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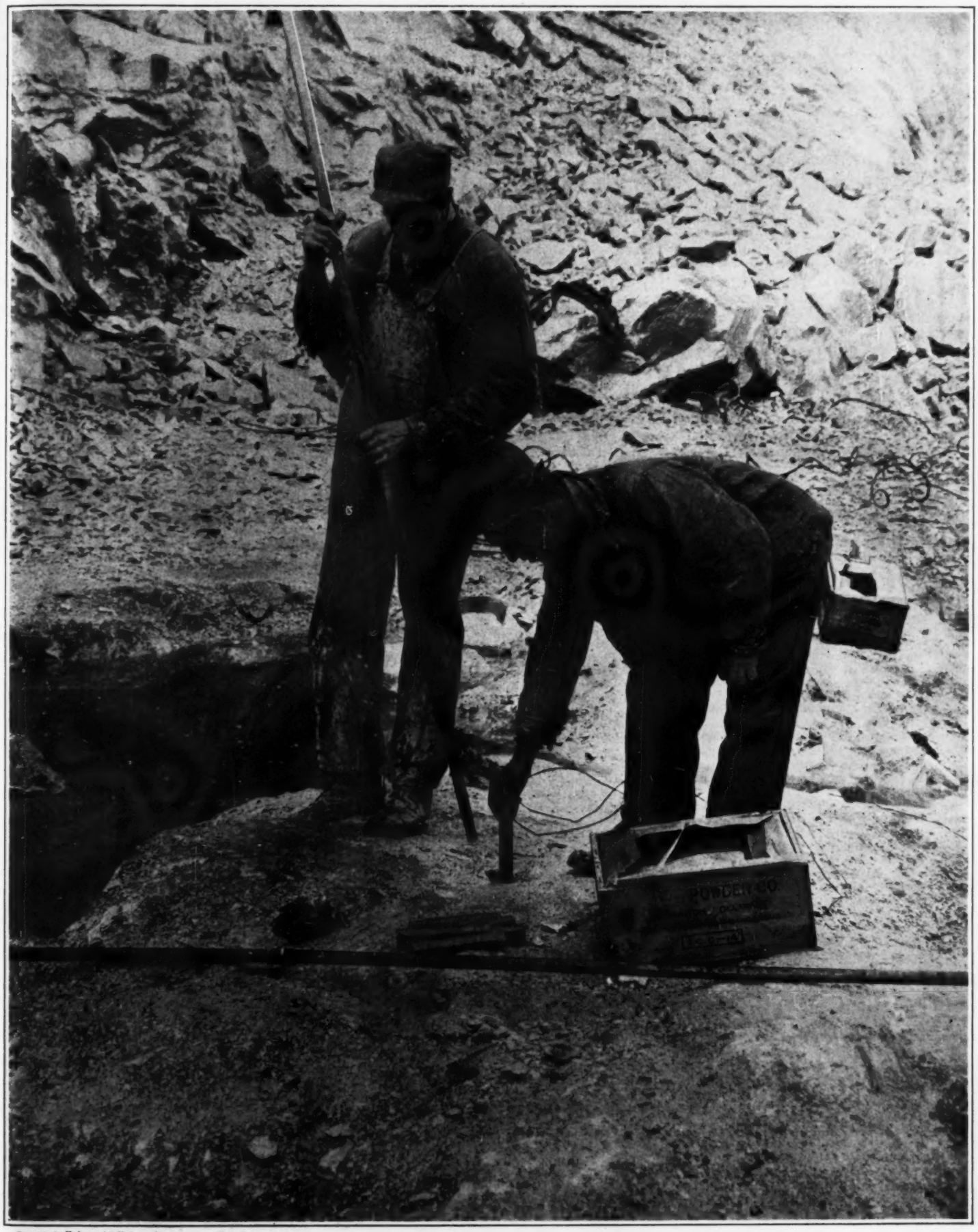

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THE MANUFACTURE OF LIME.—PREPARING A BLAST IN A LIME QUARRY. (See page 316)

Posture as a Factor in the Origin of Animal Species—I*

Variations of Attitude in the Animals of the Present Time

By Edward Perrier, Director of the Museum of Natural History, Paris

WITHOUT giving any reason for his belief, Cuvier accepted it as a fact requiring no explanation that "Animals exhibit four plans with regard to their structure, and all groups, no matter how designated, belong to one or the other of these four classes." Saint Hilaire, on the contrary, believed that there was a unity of plan in the composition of the animal kingdom, and Lamarck, while he acepted in general the main divisions of Cuvier, thought that there was a connection between them, and that their differences were due mainly to the use which the animals made of their organs. This was placing the question boldly upon entirely new grounds, since in place of accepting the existence of one or more supernatural plans in the organization of animals, Lamarck believed these creatures to be the instruments of their own structure and thus substituted the idea of evolution for the idea of primeval creation. However, since he ascribed no influence in these changes to the effects produced by the external environment, he was not able to proceed very far in the explanations which he attempted to give. Darwin, on the contrary, recognized the influence of the external world; but he did this by attributing *natural selection*, i. e., the choice of the forms to be preserved, to the *struggle for existence* and without concerning himself further with the origin of the characteristics which became fixed in the species, though these were at first mobile.

The two hypotheses of Lamarck and of Darwin may be regarded as mutually complementing each other, without being capable, however, of giving a general solution to the problem of the origin of living forms. We need not here consider Weismann's theory of the germinative plasma, of which the least that can be said is that it is extra-scientific; it makes the cause of the transformations in living creatures resident in a mysterious plasma which controls and directs these changes and perpetuates itself without ever being influenced by external circumstances. The object of explanations which are truly scientific is, on the contrary, the determination of the conditions under which the forces in operation around and about us are concerned in the causation of phenomena; this is the method which has enabled geologists to free their minds from the hypothesis of the miraculous creation of the Earth and to explain all the features observed in the structure of the earth's crust by means of the accumulation of effects produced by causes which are still operating all about us at the present time. This method, which has been called that of *present causes*, is generally attributed to Sir Charles Lyell; but it was these causes which Buffon constantly invoked in his *History of the Earth;* the geologists were turned aside from their study by the influence of Cuvier. The same method may be applied to the study of the transformations of living creatures, provided it be recollected that these creatures have been subject to various chemical, physical, and physiological influences from the very dawn of the appearance of life upon the planet and this under the most various conditions, and that these influences are still being exerted upon them at the present time; it must be recalled, furthermore, that in order to explain them, we must take into account everything which has affected them in the past and the trace of which still remains thanks to a property inherent in living substances which is called *heredity*. But how shall we reconstruct this past? The principle of the method to be pursued is to be found stated, though somewhat vaguely and more or less at random, in the musings of certain German natural philosophers. It was in conformity with the general doctrine of Oken to suppose that all living creatures recapitulate the history of their kind in the course of their embryonic evolution. But it was Etienne Geoffroy Saint Hilaire who demonstrated that during this evolution the mammals pass through phases in the course of which they exhibit a temporary resemblance to the fishes. This was later expressed by his disciple Serres in the words: "Embryogeny is a transitory comparative anatomy, just as comparative anatomy is a permanent embryogeny." We express this idea today by saying: The embryogeny of animals is only the accelerated repetition of the phases which they have traversed in order to pass from the state of the simple cell to that of their present form. Only this repetition due to *heredity* is accelerated to such a degree that these phases overlap each other, so that only their principal features persist, and so that this mutual overlapping may give birth to new characters. Thanks to this acceleration to which I have given the name of *Tachygenesis*, the heredity which originally acted as a *preserver* of newly acquired characters finally becomes a *modifier* of them. In this, therefore, we have one of the most important causes of the transformation of organisms. The phenomena of Tachygenesis had already been noted by Giard, and later by Haeckel, but without their general bearing having been perceived. These naturalists had confined themselves merely to grouping—and that quite incompletely—embryogenic phenomena into two categories: the *condensed embryogenies* and *expanded embryogenies* of Giard, the *coenogenies* and *palingenies* of Haeckel. The views of these two savants fail to agree.

Science long contented itself with demanding from embryogeny a mere cinematographic history, so to speak of the evolution of forms but these forms were produced in connection with changes in the mode of life or the conditions of existence of animals; so that it is not only the history of forms but also—and it is just this point which has heretofore been neglected—the history of the changes in the conditions of existence, which are themselves the causes of changes in the form which is revealed to us by embryogeny. And it is precisely in these latter changes that we must seek an explanation of the division of the animal kingdom into species, as we propose to show.

I have already attempted, in a book, *Animal Colonies and the Formation of Organisms*, published some years ago (1881; Masson), to explain by mechanical causes the formation of two grand types in the structure of animals: the *branching type* (sponges, polyps, Bryozoa) belonging to stationary animals whose parts are arranged in a manner very similar to those of plants, to such a degree that the medusae constitute a veritable florescence of polyps, and the *segmented type* (arthropods and annelid worms) belonging to animals which are free and mobile. These two types are independent of the nature and of the complication of the elements thus grouped, since there are found united in the same manner and forming more or less complicated clusters (and this merely because they are fixed), not only Infusoria (*Codosiga, Dendromonas, Anthothysa, Epistylis, Carcassium, Zoothamnium*) but polyps, Bryozoa, and animals higher still in the animal scale, such as the Tunicata (*Perophora* and compound *Ascidia*) while the free Infusoria (*Anoplophrya, Hoplitophrya, Opalinopsis*, etc.) form chains which are comparable to the segmented bodies of the arthropods and worms and also to the chains formed by the salpae during the process of development. Mechanical conditions alone more or less combined with either simple or tachygenetic heredity are involved in the formation of these groups. In spite of all my efforts to follow out this line of investigation I was checked and found myself unable to discover the explanation of the formation of the divisions of the echinoderms, the molluscs, the Tunicata and the vertebrates, which are precisely the ones which are the highest and the most important in the animal kingdom. This explanation remained incomplete even in the previously quoted memoir upon tachygenesis. In order to arrive at a complete explanation of the formation of these divisions we must take into consideration a whole series of phenomena which are also revealed in embryogeny but which deal with the relations of the embryo to the external world instead of with the intimate structure of its organism. The animals composing these divisions are derived from the annelid worms as is demonstrated by the initial form of their embryos, which are all characterized in the beginning by lateral symmetry and are originally encircled by perfectly circular vibratile membranes or "belts" (holothurians, crinoids, dentalids, lamellibranches) which may undergo temporarily a greater or less degree of deformation in the course of development. The temporary consequences which result from these deformations are connected with these comparatively recent adaptations of embryos which have no influence upon the definite form which they finally acquire. I have designated by the term *armogenesis* the ensemble of these adaptations; they may either simplify or complicate the young animal, at least externally, as is the case with the larvae of insects which exist either as parasites or merely sheltered armogenetic adaptations whose effects are destined to be destroyed later are the origin of metamorphoses, in fact. The embryo may also be quite clearly segmented internally at the start (*Amphioxus*).

The ancestral worms, and this is the main point to which it is impossible to give too close attention, have undergone considerable *changes of posture* and these have had for their result the formation of new divisions as remains to be explained. There is nothing hypothetical about these changes of attitude; they are still produced in the course of the development of embryos and it is even possible to discern their causes. Hitherto naturalists have been content to point them out without ascribing any particular importance to them; their interpretation, in fact, lies so far outside the bent of mind of most naturalists that I deem it advisable to precede such interpretation by setting forth various examples which prove that changes of habitual posture are frequent in the animals of the present day and especially in the species under consideration.

Among the echinoderms the so-called regular sea-urchins are spherical; they keep the mouth pressed against the ground with the anus at the opposite extremity, as in the case of the starfish; but in *Clypeaster* the anus deserts the dorsal apex and descends to the side; the portion of which the mouth remains the center becomes flattened and constitutes a ventral surface upon the edge of which the anus is placed; among the *Spatangus* the mouth quits the center of this ventral surface and becomes situated opposite the anus; in both cases these animals travel across the sand and therefore the bilateral symmetry to which locomotion gives birth is superposed upon the radial symmetry, which is scarcely altered at all. The holothurians, whose organization is similar to that of the sea-urchin, move among pebbles or in the winding crevices of rocks by the aid of five rows of adhesive tubes which run from one end of the body to the other; but many species live stretched out upon the mud or the sand and remain lying upon the same area of the body with the mouth in front and the anus at the rear. The area which habitually rests upon the mud then becomes correspondingly flattened and there finally results from this attitude a ventral "sole," which is not yet very clearly marked in Colochirus, but in Psolus, which has reached the point of climbing up the rocks, is as well developed as in a slug; the same thing is true of the numerous holothurians inhabiting great depths which constitute the entire order of the elasmopods; their dorsal surface exhibits numerous and varied aspects, while their ventral surface is flat and traversed by these longitudinal rows of adhesive tubes which serve the purpose of feet and constitute the *ambulacra;* the two dorsal ambulacra are either profoundly modified or else entirely lacking.

In this attitude the mouth of the psolus makes its appearance upon the back but in the abysmal holothurians, on the contrary, the buccal extremity is placed under the belly. Furthermore, certain *Cucumaria* bury themselves in the mud but exhibit a tendency to curve themselves into the shape of the letter U in such a manner as to turn both their digestive orifices toward the surface. This is the attitude which is adopted by a certain number of worms likewise; the *Arenicola*, the *Chetoptera*, and even certain terebellians. This attitude becomes distinctive in the upsilothurians in which the body assumes the spherical form, the swollen portion being surmounted by two vertical tubes, one buccal and the other anal. Finally these tubes become merged together in the Rhopalodina, which has the form of a child's spinning top with the two digestive orifices at the point.

The *Encrinal*, which are attached by means of a long stalk, and their relatives, the *Comatula*, which are attached only when quite young, and later become free, have both digestive orifices situated on the surface of the body opposite that which is attached to stones or sargasso weeds.

The *Synaptae*, finally, live buried in the mud, from which there extends only the buccal extremity surrounded by tentacles; their orientation is exactly opposite to that of the sea-urchins.

The attitude of the molluscs is no less varied. The Gastropods climb by means of a foot which corresponds to the arms which surround the mouth of the cephalopods; their attitude varies but little; but the case is different with the lamellibranches. The *Cardium* climbs in a normal manner; but all the lamellibranches having long siphons remain constantly immersed in the mud, with the mouth downwards; the mussels on the contrary are suspended with the mouth upward; the scallops, the oysters, and the other Monomyaria rest upon one of their lateral surfaces and the Tridacnae lie upon the back.

The crinoids, the cirripeds, and the Tunicata attach themselves to a solid support by the anterior extremity of the body and remain suspended in this position. If they attach themselves to the lower surface of the object which supports them the mouth is held downwards; if they attach themselves on the contrary to the upper surface then the mouth is turned upward. Among the crustaceans the Apus and the branchipeds swim lying upon the back; the same thing is true among insects, namely, in the case of the Notonecta, which owe their name to this peculiarity. Among the gastropod molluscs those which swim (Ianthines, Carinaria, Firoles, etc.) always swim with the abdomen in the air. This is also the attitude adopted by the Aplysia when they begin to swim by the help of the turned-up lobes of the foot which they habitually employ to climb with.

It is a well known fact finally that the turbots, the soles, the dabs, etc., both rest and swim lying upon one side, a circumstance to which they owe the name of Pleuronectes, the order to which these fishes all belong. We may compare with these facts the biped position of birds and of man.

(To be continued)

*Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from *Scientia* (Bologna).

Chemical Danger-Signs for the Machine Operator*

A Suggested Means for the Detection of Overheated Machinery and Bearings

By H. T. Pinnock

It is an axiom, theoretically established and proved practically, that some degree of friction and consequent heat generation is inseparable from machinery in motion. Half a century ago, breakdowns of machinery from this cause were more the rule than the exception, but with modern improvements in design and construction and more specialized knowledge of lubrication and lubricants, trouble from this cause has been reduced to an extent that was previously thought impossible. There can, however, be few, if any, industrial undertakings where trouble has not, at some time been caused by overheated bearings and the like; trouble due to dirt, inattention, or failure of the lubrication system. Such occurrences, even today, are not infrequent and the result may often mean a complete or partial stoppage of the machinery involved, coupled with expensive repairs owing to "galling" of the moving parts. Trouble of this kind naturally occurs most frequently with machinery in inaccessible places; for instance, in a line of overhead shafting, the first visible indication may be the emission of blue smoke from the overheated oil in the vicinity of the bearings, by which time both bearing metal and shaft may be badly galled.

It is obvious that if warning could be given as soon as heating up occurred, but before it became serious, much trouble and expense could be avoided and the matter could be rectified in time. With this object in view, various devices have been introduced from time to time, which have consisted mostly of indicators operated by thermo-electric couples, or of expansion methods. Tonner, in America, suggested the use of copper mercuric iodide on the axles of railway rolling stock as an indicator of overheating. This suggestion, however, does not appear to have been carried out to any extent; it is difficult to see why, as under suitable conditions some such compound appears admirably suited to the purpose.

The attention of the writer was directed to the matter about 1908, and he was then in ignorance of Tonner's suggestion, but was led to investigate the properties of the double iodides of mercury with other metals, for the purpose of finding a suitable compound which would serve as a detector of overheated bearings. These double iodides were all found to possess the property of undergoing a reversible transition involving change of color when heated and subsequently cooled. With most of them the change was comparatively slow, and the transition was so gradual and spread over so large a range of temperature as to be unsuitable for the purposes required. Other compounds changed fairly sharply, but the range of color passed through was too slight to be of any practical value.

Two compounds were, however, eventually prepared which gave promise of considerable utility. The first of these was the double iodide of silver and mercury, $AgI.HgI_2$, which is a pale lemon yellow powder at ordinary temperatures, and changes to a vivid carmine color at about 90°—100° C. the change in both directions being fairly sharp. The other was the copper mercuric iodide, $Cu_2I_2.2HgI_2$, which Tonner had previously described. This substance is a very vivid scarlet vermillion at ordinary temperatures and at 60°—70° C. it changes to a chocolate brown. Both these compounds are adapted for use under suitable conditions, but it was found that a mixture of the two, consisting of 85 per cent of the copper salt and 15 per cent of the silver salt, was more sensitive and gave a greater color range from vermillion to almost black, the transition being exceedingly sharp. (Other mixtures were prepared for special conditions, but the above was more generally applicable.)

The compounds may be prepared in a variety of ways; for instance, a very simple method of preparing the copper salt is by well triturating in a mortar 380 grams of cuprous iodide with 910 grams of mercuric iodide, sufficient water being added to form a paste. When thoroughly mixed, the mass is dried in the water oven, and the dried mass ground to an impalpable powder. Another method is to dissolve the mercuric iodide in excess of potassium iodide solution and precipitate the double salt by the addition of copper sulphate solution. The silver salt can be prepared in a similar manner by double precipitation. Whichever method is adopted, the product should be well washed to eliminate soluble impurities, as these appear to retard the color change, as well as to affect its character.

Having prepared the double salts and mixed them in the proper proportion, the means of applying them arises. It has been found convenient to convert them into a varnish-paint or enamel, by incorporating the powder with a colorless varnish medium that will stand moderately high temperatures without softening. A good white shellac spirit varnish such as is used on electrical machinery has been found suitable for most occasions, as this will stand a low stoving temperature, but for more elevated temperatures, a medium such as is used in the high temperature aluminium paints used for steam pipes, etc., and which will resist temperatures up to 200° C. is excellent. About 100 grams of compound to 70 c.c. of medium will be found a mixture of suitable consistency.

A convenient method of applying this heat detector is first to paint a white circle or ring on the bearing or other place which it is desired to keep under observation, using a zinc white paint. This white circle is applied to the journal or housing of the bearing, and the detector paint is applied as a vivid red bull's eye in the middle of this, thus forming a very striking object which is visible from considerable distances. It must of course be applied to the block of metal as near as possible to the point at which the heat is likely to be generated. It is sometimes desirable to apply the paint to the shaft itself, just where it extends beyond the bearing metal, and in this case, a convenient method is to apply a broad band of white paint with a narrower band of the red detector paint in the center. This red band in the center of the white one is then easily seen as the shaft rotates. In any case, after the paint is dry, it should be protected with a coat of colorless oilproof varnish, so that the surface may be occasionally wiped free from dust and dirt.

The visibility of the paint against its white background is very high, the bright scarlet color being visible from long distances without effort, and the change at 60°—70° to black is very easily observed, the visibility of the black on the white ground being very much lower. It is generally easy to arrange matters so that the detector is placed in a position where it is visible almost without conscious effort; and experience has proved that a workman is easily trained to cast his eye occasionally on the detector, while he could not be depended upon to climb up to the spot and feel the bearing on the remote chance of finding it heating up. When the paint changes color, there is certainly something wrong, but generally speaking, it will be found that the matter is taken in time, and that no damage is done, the bearing simply requiring cleaning and adjustment without serious stoppage and expense.

This detector has also been successfully used on a gas engine, one of the main bearings of which was frequently heating up, owing to a slightly distorted shaft, and it was possible to place good big "bull's eyes" upon it, which on many occasions gave warning of impending trouble, enabling the load to be reduced before damage was done. It was also found of service on the water-jackets of large internal combustion engines to give warning of insufficient circulation of cooling water.

Many other instances occur in which this property of the double mercuric iodide compounds may be taken advantage of, for instance, it may be used in the reverse way on air-heating towers and the like. A case in point is that of a producer gas plant where the air supply is saturated with water vapor at about 70°—75° C. If the outside of the tower has a white circle about 3 feet in diameter painted on it, with a center about 1 foot in diameter of the detector paint, the appearance of a red color, visible all over the plant, is a sign that the saturation temperature has fallen too low and requires attention. The same applies to feed water heaters for boiler feed water.

Where rather high temperatures require indication, the silver compound which undergoes transition at about 90—100 C. may be employed, to draw attention to the fact that the water is boiling away and may need replenishing. The application to vacuum evaporators, exhaust turbines, etc., is also indicated.

The writer has had some of these indicators in action for the past ten years and the color change is just as sharp and distinct now as when originally installed. The varnish medium has in some cases called for renewal, but as no special precautions were, at that time, taken in the selection of the most suitable medium, this result is not unnatural. If a really good medium such as is employed in radiator paints be selected, the varnish should endure under normal circumstances for very many years.

*From the *Journal of the Society of Chemical Industry.*

Glycerin Manufacture by the Fermentation of Sugar

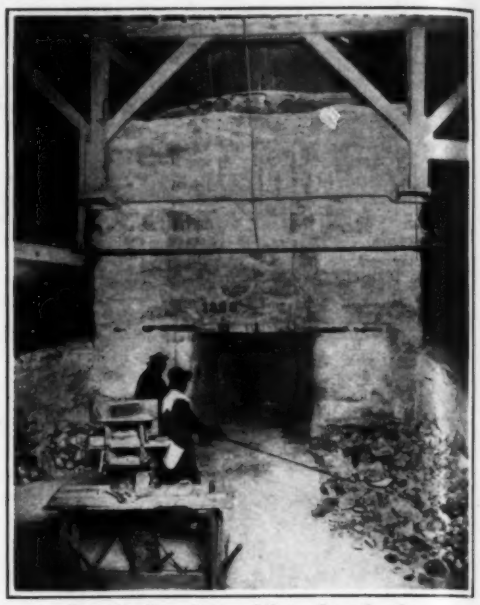
It has long been known that the ordinary alcoholic fermentation of sugar yields about 3 per cent of glycerin, and the study of the fermentation has shown that the conditions favoring a rapid fermentation, by the selection of a suitable yeast and by feeding the yeast with nitrogenous compounds also favor the production of glycerin. Under ordinary conditions there is little object in increasing the glycerin percentage; when the explosive industry found a valuable material in glycerin, the fermentation process received further attention, and some glycerin was, in fact, isolated from the distillery residue before the war. But the fermentation process for the manufacture of glycerin was not worked out until the blockade deprived Germany of the imports of fats. It was rumored during the war that the protol of the Protol Company was a fermentation glycerin due to the researches of Lüdecke and Connstein. Particulars were not published, but they have recently been given by Connstein in the *Wochenschrift für Brauerei* of May 10, 1919. It would appear that as many as 63 factories were at one time engaged in this glycerin manufacture, but that only a few persevered with it. Yet an output of 1,000 tons per month is spoken of. The first important fact established by Lüdecke was that to produce glycerin, the fermentation should proceed in the presence of an alkali, and that sodium sulphite, a relatively inexpensive alkaline substance, answers very well. This sulphite has the advantage of not injuring the yeast, which is very sensitive to some chemicals. A solution of 1 kg. of sugar on 10 liters of water, to which 400 grammes of the sulphite are added together with the usual food for the yeast, alkali phosphates and sulphates, was completely fermented by 100 grammes of yeast in a few days. Quantitatively the products were 20 per cent and more of purified glycerin, 27 per cent of alcohol and 3 per cent of aldehyde. There is, of course, always considerable evolution of carbon dioxide. In general the glycerin percentage rises with the amount of sulphite present, while the alcohol percentage decreases at a roughly corresponding rate. To separate these products the yeast is filtered off; the alcohol and aldehyde are recovered by distillation; most of the salts are precipitated by adding calcium chloride and sodium carbonate to the liquid and are therefore partly recovered as well, and the glycerin is finally obtained by distillation. This latter distillation is not free of difficulties, as is the case also when glycerin is manufactured in the ordinary way by the decomposition of fats; the new process had other serious difficulties to overcome. On the other hand, it is said that any sugar and also molasses and any kind of yeast will do, and that the fermentation temperature has practically no influence; the yeast, though modified, can be again used. These statements do not quite agree with the results of experiments which were started in the United States by J. R. Eoff, W. V. Linder and G. F. Beyer, of the Internal Revenue Bureau, when information about the German process had leaked out. An account of these researches was given by Arthur R. Ling in the *Journal of the Society of Chemical Industry* (London) of May 31 last. The American experimenters recommend pure cultures of saccharomyces ellipsoidus (var. Steinberg) and 5 per cent of sodium carbonate gradually to be added to the sugar solution fermented at a temperature of 30 deg. or 32 deg. C., and they are, on the whole, more restricted as to the conditions of the fermentation. They worked with Porto Rico molasses, known as "black strap," but their glycerin was not pure, and the financial chances of the process did not look favorable.—From *Engineering* Sept. 5, 1919.

Mineral Wealth of Morocco

Too little is at present generally known of Morocco to allow a full estimate of its mineral wealth to be made, but we know enough to justify the prediction of an important future for that country from the industrial point of view. Foremost among its riches are the deposits of manganese ore, on its eastern side. These played an important part in the preparation of munitions for France during the war, 10,000 tons of manganese ore a month being required. Now, when the small deposits in France are exhausted, those of the Caucasus, which formerly provided the main supply, become for the present unavailable, and the whole production of Brazil being absorbed by the United States steel industry, France is attaching more importance to Morocco. Besides manganese, and next in importance are the rich phosphate deposits of El Borudj, which are attracting attention in France as an easily accessible source of manures. These deposits are of wide extent on the plateau between Guisser and El Borudj. They are being surveyed with a view to connect them with the cultivated land. There are, besides, considerable deposits of iron ore, as well as petroleum and bituminous shales. —*Zeitschrift für angewandte Chemie.*

A large limestone quarry near Rockland, Maine

A train load of limestone on its way to the kilns



Drawing lime from a kiln and sorting it

The Manufacture of Lime

The Conversion of Limestone into "Quicklime"

By W. J. Faber

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OWING to the extensive beds of natural cement rock in this country the lime industry has received little public attention. In Europe, on the other hand, lime is burnt with clay to produce cement, and consequently the lime industry there is of greater importance than it is here in the United States. Despite the fact that lime has been, to a considerable extent, displaced by cement in the building trade, there is still a very extensive field for this material for mortar, whitewash, the manufacture of bleaching powder, the removal of hair from hides, the production of fungicides, and the manufacture of certain kinds of glass, so that the manufacture of lime in this country is far from an unimportant one.

Every one knows that "quicklime" or calcium oxide, is produced by burning limestone in kilns, but just what takes place when the stone is subjected to heat is more or less a mystery to the general public. Calcium oxide does not exist in nature in the uncombined state, but in limestone it appears as a carbonate of calcium, the chemical symbol of which is $CaCO_3$. The problem is to remove CO_2, or carbon dioxide, from this combination, leaving CaO, or calcium oxide. This is accomplished by heating the lime to a cherry red. Pure carbonate of lime contains 56 parts by weight of calcium oxide and 44 parts of carbondioxide, so that after all the carbon dioxide has been driven off in the kiln there should remain 56 per cent of the original charge of stone in the form of quick lime. However such a high yield is seldom obtained in practice because of the presence of moisture in the limestone which is also driven out by the roasting process, thus further reducing the final yield. If the lime burner gets half a pound of lime for every pound of limestone he may be well satisfied. Of the lime that comes from the kiln 40 parts by weight are metallic calcium and 16 parts oxygen, but it is impossible to disassociate the oxygen from the calcium at the temperature obtainable in the kiln.

There are two ways of charging a kiln. The older method consists in placing alternate layers of lime and fuel and then firing the whole mass. The fuel may be wood, charcoal or coal. A temperature of between 850 and 900 degrees Fahrenheit is maintained for about 72 hours, when, the carbon dioxide having all been driven off, the kiln is drawn and a fresh charge of raw materials is introduced. But now-a-days the entire charge is not drawn at once; instead there is a continuous draw of lime, fresh material being introduced at the top from time to time while the lime is being drawn from the bottom.

As the lime produced in this manner of firing is more or less mixed with ashes modern kilns are devised with a separate fireplace in which the fuel does not come into actual contact with the limestone. This results in some waste of heat and consequently more fuel is consumed, but a purer lime is produced.

In order to expedite the calcining process moisture is usually introduced into the kiln. Either a steam jet or a pan of water is provided or the limestone is wetted before being introduced into the kiln. The favorable action of moisture is due to an interesting principle of physics which was first pointed out by Gay-Lussac, the eminent chemist. Under the law of diffusion of gases a vapor or gas will enter and spread out into a space occupied by a vapor or gas of different composition as readily as it would in a vacuum, but if introduced into a space occupied by a gas of the same kind it must overcome the pressure of that gas and its diffusion is retarded. Carbon dioxide will pass off more freely into an atmosphere filled with vapor than in one filled with carbon dioxide. As it is being generated in the kiln the carbon dioxide has constantly to overcome the pressure of that already evolved and the introduction of vapor helps to clear away the gas and make room for the diffusion of fresh gas as it is evolved. This was illustrated by Gay-Lussac who heated a bit of marble in a glass tube set in a furnace. When the temperature had been raised sufficiently to generate the gas in large quantities the draft was checked. Although the marble remained at a red heat the gas ceased to be evolved. Then steam was introduced into the tube and the gas began again to be evolved copiously.

The lime burner's process is a very simple one. All he needs to do is to burn out the carbon dioxide. Just why wetting the stone expedites the calcining process he cares not. Experience has taught him its advantages. As for complicated reactions such as take place in the production of cement, he has none of them to bother him.

A battery of lime kilns at Rockland, Maine

The stone before calcining

Machine for separating coarse from fine lime

The Shop Lubricating Problem

By Raymond Francis Yates

THE supply of lubricating oil purchased by the average shop is generally large enough to justify a careful examination of its properties to determine whether or not it meets specifications and if it is the same as the sample rendered to the purchasing agent. The work necessary to determine the different values regarding the properties of the oils purchased does not involve a great expenditure of time or money and with the aid of the information and apparatus described in this treatment, any young man of average intelligence can conduct the tests with every assurance of reliable results.

About the most important property of an oil is its viscosity and this is also the only characteristic that will give any reliable indication of its lubricating value. Viscosity is the degree of fluidity in ordinary terminology. If an oil is "heavy" it is said to be viscid in technical parlance. If it is "light," or "thin," its viscosity is said to be low. Viscosity is really an indication of the molecular or internal friction of a lubricating oil—the resistance offered by the molecules sliding or passing over one another. The viscosity of an oil tells just what pressure it will support when serving as a lubricant and this is a very important factor to know if a shop is to be lubricated efficiently.

There are several reliable methods by which the viscosity of an oil can be determined. The one most adaptable to small shop use will be described. It operates upon a very simple principle, easily understood. A specific quantity of oil at a definite temperature is permitted to flow through an orifice of given dimensions. With the time required for this, all the necessary factors in figuring the viscosity are available. The instrument needed to make determinations in viscosity is extremely simple and can be readily made. Standard viscosimeters can be purchased from scientific supply houses, but they are very expensive and the small difference in accuracy between them and an instrument made in the shop is not great enough to justify the expenditure. The instrument described in the following lines should by no means be regarded as a makeshift. It is a practical outfit entirely reliable for all ordinary purposes.

The general constructional features of the viscosimeter is shown in Fig. 3. A double container is made first. This consists of an outer tin container in which another small brass container is concentrically arranged. The brass container should have a capacity a little in excess of 55 cc. and its interior surface should be nicely polished. Knowing the difficulty of getting a small brass container of this size and shape the author designed the instrument so that a small brass tube could be used to replace the brass container. The tube can be soldered into place as shown. It is well to see that the resulting joint is perfectly water-tight. Otherwise, water will find its way in and thereby cause a serious interference with the results. The orifice provided in the bottom of the apparatus should be made from a piece of brass drilled out to the proper size. It will be necessary to experiment to produce the proper size of hole. The hole should be just large enough to permit 55 cc. of water at 65 degrees Fahrenheit to pass in 15 seconds. This requirement does not necessitate a great amount of painstaking experiment. It will be necessary to start with a small drill and increase the size of the hole with a drill a size larger until the orifice is of the proper size. This involves little work and a stop-watch is the only unusual device needed. Three feet should be provided for the instrument. These can be made from ¼ brass stock or any other stock available. Three holes are drilled in the bottom of the outer container and the rods are provided with a thread at the end. By means of two small brass nuts the legs can be held in place. After the screws are tightened, solder should be flowed around the edges, to prevent leakage of the water.

A small support is provided to hold the thermometers. The construction of this part of the instrument is clearly shown. It will be noticed that means are provided to adjust the thermometers. The thermometers used should be of the conventional size and form, similar to those employed in chemical laboratories. The cheaper article will suffice and it will not be necessary to lay out over a few dollars to obtain them. One thermometer is suspended in the water and the other is immersed in the oil. It is understood, of course, that both thermometers should be calibrated with the Fahrenheit scale. To complete the instrument, a 50 cc. chemical flask will be needed.

Now, having covered the construction of the viscosimeter, attention will be given to its use. Care is more important than skill in manipulating a viscosimeter. An ordinary stop-watch will be a necessary addition to the outfit. About 55 or 60 cc. of the oil to be tested is placed in the brass container. Water is then placed in the outer container and the level of the water is brought to the same height as that of the oil. The thermometers are then put in place and the heat applied to the outer container. A glass stirring rod is employed to agitate the water continually which helps in the production of a more uniform temperature. It is known that the temperature of water rises much more rapidly than oil and for this reason it will be necessary to withdraw the source of heat occasionally in order to permit the oil to "catch up" to the water. The thermometers should be watched closely and at the instant they both read 65 degrees, the plug should be withdrawn and the oil permitted to flow into the 50 cc. chemical flask. At the instant the plug is withdrawn, the stop-watch is started and it is stopped when the oil level reaches the 50 cc. mark on the flask. Knowing the time required for 50 cc. of oil to run out, the viscosity of the oil can be very easily determined.

When a purchasing agent receives a sample of oil from a refinery, the viscosity of the sample should be determined. When the consignment is received, the viscosity can be checked against the viscosity of the sample.

After the viscosimeter has been used, it should be very carefully cleaned out and put away for future use. The interior of the oil container should be cleaned with a swab soaked in gasolene.

Many times, oil contaminated with acid finds its way on the commercial market. This invariably results from improper washing at the refinery. Of course, every oil contains an infinitesimal amount of acid, but a dangerous amount is often present, and, when it finds its way into bearings, trouble is sure to result.

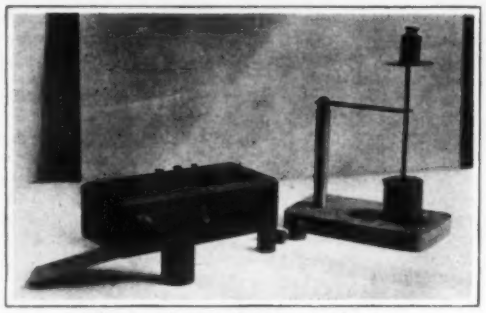

Fig. 1. Grease viscosimeter in use

The acid test is a simple one and can be carried out with little trouble. A small sample of the oil to be tested is placed in a test tube and a little real hot water is poured in upon it. The contents of the tube are then thoroughly shaken. After this it is permitted to stand undisturbed until the water is separated from the oil. The water is then poured off and tested with litmus paper. The litmus paper is immersed in the oil and if acid is present, the paper will be turned red. This test will not give any indication of acid unless there is a considerable quantity present.

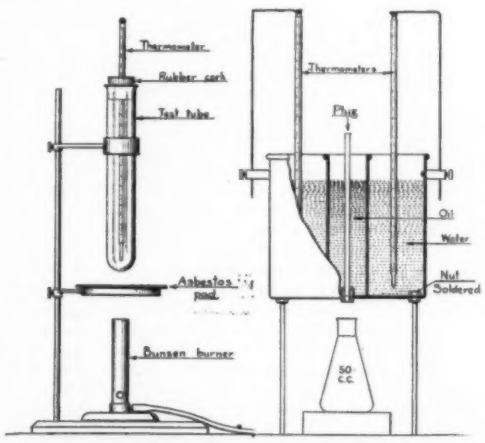

Fig. 2. Determining the melting point of grease

Fig. 3. Construction of the oil viscosimeter

The flash point of a lubricating oil is that temperature at which combustion takes place. The more viscid oils have a high flash point while lighter oils have a low flash point. The flash test is important for oils that are to be used in high temperatures, such as those employed on gas or Diesel engines.

To make this test, the sample of oil is placed in a small evaporating dish. This dish is then surrounded by a sand bath. A blast burner is then applied to the sand and the temperature of the oil is raised. A thermometer is immersed in the oil before the heat is applied. When the temperature of this oil has reached 300 degrees Fahr. or more, a flame is brought into proximity to its surface. This is done at regular intervals—for every 5 degrees raise in temperature. When the temperature has risen to a certain point, little blue flames will shoot across the surface of the oil when the large flame is brought near the surface. When this occurs, the flash point is being approached. When the temperature of the oil has reached the flash point, a flame will appear upon the surface and remain. The temperature should be read from the thermometer at this point. If the reading is 512 degrees Fahr. the flash point of the oil can be regarded as 512 degrees.

The testing of lubricating grease is a very important item as considerable quantities are used in the average shop. Like oil, the viscosity test for grease is a fair indication of its lubricating value, but, on the other hand, it gives absolutely no indication of the other physical properties of the grease. The little instrument shown in Fig. 1 is all that is necessary to determine the comparative viscosity of different greases. If a sample of grease is received, its viscosity, as found by this instrument, can be noted and a sample from the consignment received checked against it.

The grease viscosimeter is easily made, as a glance at the photograph will show. A small polished brass rod with a sharp point is held in a small standard. A one ounce weight is fixed to the top of the brass rod and the time required for this rod to sink to the bottom of a cup filled with the grease is noted. The time is found by the use of a stop-watch. A small mark should be made on the brass rod so that it will be even with the top of the standard when the point of the rod has come to rest at the bottom of the grease cup. The grease should be filled very carefully and *not packed*. A straight-edge should be employed to level off the top of the cup when it is filled.

The melting point of grease can be determined by the use of the apparatus shown in Fig. 2. This is an extremely simple device and it can be put together with little trouble. A small test tube and chemical thermometer constitute the main elements of the device. The test tube is provided with a rubber cork through the center of which the thermometer passes. The test tube is held in a stand such as is used in chemical laboratories. To make the test, the tip of the cold thermometer is smeared with the grease to be tested. It is then inserted in the test tube through the rubber cork. In doing this it will be necessary to slip the cork over the top of the thermometer so that the grease at the tip will not be wiped off. After the tube with the thermometer is mounted in place, a bunsen burner is brought under the device. A small asbestos pad is placed between the flame and the bottom of the test tube. The temperature is then slowly raised. As the temperature rises, the grease on the tip of the thermometer will become more fluid. When this happens the grease should be watched very closely. As the temperature rises, a drop of liquid grease will be seen to accumulate at the tip of the thermometer. As the drop falls to the bottom of the test tube, the temperature as indicated by the thermometer should be noted as this is the melting point.

Heat Treatment of Duralumin

A SERIES of tests have been made for the National Advisory Committee for Aeronautics to establish further the laws of the effect of varying heat treatment conditions with the following conclusions:

There is not in the case of the duralumin type of alloy, as there is in the case of steel, a definite quenching temperature which marks the limit of the property of the material to harden; duralumin may be hardened by quenching (followed by ageing) from temperatures varying from 250 deg. C. to 520 deg. C., and the hardness obtained by quenching from these temperatures increases uniformly as the quenching temperature increases, reaching a maximum at the latter temperature.

Duralumin, on the other hand, is similar to steel in the fact that the tempering of it or ageing after quenching is determined by two factors: time and temperature. A temperature of 150 deg. C. marks what may be called a critical temperature with respect to the ageing of duralumin; *i. e.*, above that temperature continued ageing may cause a decrease in hardness after the maximum hardness is attained, whereas below that temperature no such subsequent decrease of hardness occurs. The lowest temperature at which the maximum hardness may be obtained is approximately 125 deg. C.

The period of time of holding the specimen at the quenching temperature before quenching has but an inappreciable effect on the properties obtained; on the other hand, an improvement in the hardness of specimens quenched from temperatures below from 500 deg. C. to 520 deg. C. is obtained by preheating them before quenching to the latter range of temperature. Specimens held for 21 hours at the higher quenching temperatures before quenching (515 deg. C. to 525 deg. C.) were blistered with consequent decrease in hardness.

The following tensile properties have been obtained on rolled sheet of the above composition:

Tensile Strength	Proportional Limit	Elongation in 2 inches
Pounds per sq. in.	Pounds per sq. in.	Per cent
60,000	40,000	6
60,000	30,000	20

These properties may be obtained by quenching from 515 deg. C. followed by ageing for one week at from 125 deg. C. to 150 deg. C., depending upon whether a high proportional limit with low ductility is desired (ageing temperature of 150 deg. C.) or the converse.—From *Automobile Industries*.

A Possible Limit to Gravitation*

Are the Larger Galaxies Intimately Related Cells of a Great Organism?

By Frank W. Very, Westwood Astrophysical Observatory, Westwood, Mass.

It is assumed that gravitation acts by means of longitudinal waves of alternate condensation and expansion in a universal medium which is also a magnetic medium, or "magnetic aura," composed of least parts, or magnetions, and which is subject to magnetic laws. Hence the gravitational wave at any instant is assumed to coincide with a magnetic equipotential surface and to follow in its progressions the curves of magnetic lines of force. Reasons are given for believing that the sphere of action of a given galactic mass of stellar material does not extend to infinity, but is contained within a definite aural "cell," or is limited by the vortical motions of a particular body of the universal aura which is independent of neighboring similar bodies, possibly because there is repulsion between them, so that interference is impossible. Speaking relatively, the galaxies are rather closely packed, in total disagreement with the sparsity of stellar distribution; and the galaxies have also much greater speeds than the relative speeds of the stars which compose them; but nevertheless the galaxies show hardly any appearance of collision or interpenetration—nothing which cannot be explained as variation in a general magnetic control.

In confirmation of this view may be cited Van Maanen's measures of the internal motions in Messier 101. The motions are *aicay* from the center, as if controlled by currents in the general medium, that is, these motions are not such as would be anticipated under the gravitational attraction of a central mass; and the flow appears to follow a law of the inverse *cube* of the distance which would be appropriate to a magnetic control. An attempt is made in this paper to devise a scheme of an atom, composed of least gravitative units, which shall be capable of performing these functions and of sustaining these relations to a general magnetic medium; and it is shown that gravitational waves having a frequency not far from that of a light-wave will account for the phenomenon, if circumscribed by a boundary; but that, otherwise, it is not easy to account for the action on mechanical principles. Hence it is concluded that, somewhat as the molecules of gases move in every direction among themselves, but are nevertheless controlled by the more general currents of the larger gaseous mass, so the individual motions of stars, or of lesser star clusters, are local and under the control of a more general movement of the body of aura which contains them.

According to the kinetic theory of gases, the pressure in a gas is that due to the momentum of the colliding molecules themselves as finally reflected from the containing walls of the enclosure. Without a limiting wall, the given mass of gas would expand indefinitely until its molecules ceased to collide and there would be no pressure. In a galactic mass, on the contrary, the individual stellar units do not collide, and the compression is not produced by the onward motion of the stellar "particles," or of their least component atoms; but it is produced in the containing medium by an internal mechanism within the atom itself, thus in an entirely different way. Nevertheless, as in the case of the theory of gases, it is difficult to see how there can be any *pressure* unless there is a retaining wall. Such a cell wall for the gravitational pressure is presumably a discontinuity in the aura produced by its vortical motion. Thus the aural cell may be likened to a gigantic "vortex-atom."

GRAVITATIONAL POTENTIAL IS A STRAIN IN THE MAGNETIC MEDIUM CAUSED BY ELECTRIC STRESSES.

Until quite recently, one of the chief characteristics of gravitation has been supposed to be its universality. The attraction of large and small neighboring masses in the Cavendish experiment, the union of sun and planets, and of pairs of suns forming binary stars and separated by distances much exceeding those of the planets, all appeared to follow Newton's law with remarkable accuracy, and to be completely dissociated from every other form of physical force. No mode of screening this force has yet been discovered. If limitations to gravity exist, they must be sought in other ways.

Gravitational potential appears to consist in a state of strain set up in the magnetic medium through the interaction of waves in the medium which constitute the external gravitational field of the electronic movements which *are* matter. We admit that matter is first of all a circulatory movement of the two sorts of electricity (equivalent to an electric doublet) whose least components are everywhere accompanied by indefinitely extended and dynamically proportional vortices in the magnetic medium. It would appear, however, that, though no other than the magnetic medium can be concerned in the action, and though the gravitational lines of force are ultimately controlled by magnetic vortices, the gravitational forces are not to be confounded with magnetic forces.

Rutherford maintains that the positive electricity in an atom is a central mass of very minute size, placed there like a sun (as in Larmor's atom) to guide the orbital motions of the electrons. It has been supposed that the positive nucleus of an atom must be very minute, because collisions of alpha particles with them are infrequent; but contact in this case does not mean hitting the bull's-eye of a target. It means a sufficiently close juxtaposition of two interpenetrating fields of motion in the magnetic universal atmosphere to produce reaction; somewhat as the fields of force of light-rays everywhere interpenetrate except where there is an exceptionally precise superposition of the extended fields, with similar, or with opposing phases, reinforcing the movement on the one hand, or destroying it on the other.

Now this assumption of central position is unnecessary; because Newton showed that the gravitational attraction of a spherical shell of matter is precisely the same as if all of the matter in the shell were concentrated at the center. Nor do we know just what it is that constitutes what we call an "attraction." A soap bubble is held together as one piece by a circumferential pressure everywhere centripetally directed. We explain this as the result of surface tension in a liquid; but if we were ignorant of the existence of the surface tension, there would be nothing to distinguish this from a case of central "attraction." Moreover, if all of the positive electrification is concentrated in a single electric mass, it would follow that the heaviest atoms must have the smallest central nuclei (because intensity of electrification increases as the radius diminishes), which seems a bit paradoxical, since it is natural to suppose that increased mass comes from the addition of new accessions, and this could happen if we suppose that the minute positive electrons are symmetrically arranged in the form of a thin shell. It is also in accordance with all of the electrical analogies that the static part of the electrification should seek the surface. The rapidly moving electrons are elements of electric current, but this does not prevent them from also playing the part of static charge in potency, even though this charge may be neutralized.

GENERAL SCHEME OF ELECTRONIC MOTIONS WITHIN THE NUCLEUS.

In considering the motions of the negative electrons, some modifications are needed. The Larmor-Bohr-Rutherford atom is likened to a solar system in which the negative electrons, like the planets, move substantially in a single plane. This may be true of certain satellite electrons concerned in chemical action, but I would suggest that not all of the orbital planes need coincide. The larger part of them may be parallel, but distributed on the spherical surface of the atom. The resultant effect will be the same in many respects as if all were in one plane. This leads to a consistent scheme of motions according to the following plan:

Assume as a preliminary conception that all of the electrons in a meridonal section of the atom are either ring-shaped, or else approximately oblate spheroidal particles of a uniform size (equatorially expanded by centrifugal pressure of the spin) and with a common (let us say, clockwise) rotation over a given half-section as seen from our point of view; and that they are revolving rapidly in planes parallel to the equator of the atom (with the electrons juxtaposed, pole to pole, or forming virtual vortex-filaments) in definite, but not necessarily invariable orbits, since they may pass into spirals whose *radii vectores* alternately expand and contract when the elastic surface of the atom is disturbed by a collision. The electrons having like rotation mutually repel one another, except in the direction of the spiral vortex-filament; and this may compel some motion of the orbital planes and change of configuration of the orbits during radiation. Juxtaposed electrons on either side of an equatorial plane are mutually repelled polewards, and this would split the atom into two halves were there not a restraining force.

The electrons are supposed to be rotating at enormous speeds and all in a given set in the same direction of spin in respect to the orbital motion, which will necessarily give the appearance of opposite rotations in the two halves of the same meridianal section of the atom. We must presume that these motions are so nicely balanced and take place in a medium so free from viscosity that they form a perpetually regenerating system.

Particles of the sort described are supposed to attract outside particles in proportion to the energy of the electronic motion, and this will vary in direct proportion to the number of electrons included in the atom. The attraction will apparently be that of *pulsatory* motion, or will form waves of longitudinal vibration in the universal aura, passing outward into forms which at first approximate to perfect spheres. Owing to the perfect sphericity of the atomic surface, the combined vibrations of its electrons will generate a composite spherical wave in any case. The orbital motions give rise to vortices in the magnetic medium which are the cause of inertia, and the pulsatory motions produce the changes of density which are the origin of gravity. The conception, it seems to me, affords a rational basis for the conclusion reached by Fessenden on general physical principles, but without attempting to devise details of mechanism, namely, that "the inertia of matter is due to the electromagnetic inductance of the corpuscular charges, and gravitation is due to the change of density of the ether surrounding the corpuscles, this change of density being a secondary effect arising from the electrostatic stresses of the corpuscular charges."[1]

THE NATURE OF POSITIVE ELECTRICITY.

As to the nature of positive electricity which is always associated with the negative electrons in the atom, we know nothing, save that it has opposite properties to negative electricity, so that if the shell of positive electricity is composed of discrete *positive* electrons, arranged in circular strands which revolve in the same general direction as the negative electrons and nearly parallel with them (though the discrete positive electrons may be *rotating* in the opposite sense to the subjacent negative ones), the magnetic field of the positive electrons will have the opposite sign to that of the negative electrons. The positive strands will repel each other, and the positive shell will be strained almost to the bursting point, being retained in position solely by the attraction of the enclosed sphere of negatives. In this view, the sun-and-planets analogy does not hold in the atom, at least not as to the gravitational properties of the nucleus, but *the positive and negative masses are presumably of a like order of magnitude or even identical save in aspect;* and they are complementary in the sense that one requires the other, whereas we can conceive of a sun without planets. If the two spheres are not exactly concentric or not perfectly equal, they form the equivalent of a doublet,[2] and the total electric value of the combination is that of a minute residual, or *difference*, while the gravitational effect is that of the sum of the gravitational forces which do not interfere.

If the combined revolutions and potencies of positive and negative electrons are exactly adjusted, there will result a magnetically neutral atom; but if there is a difference in the positive and negative revolutionary fields within the atom, it becomes a maguet.

THE QUESTION OF ORBITAL SPIRALITY.

Professor G. Johnstone Stoney has been the only one I know who has attempted to apply the doctrine of spiral orbits of electrons to explain harmonic series in spectral lines, finding in the case of the A and B groups of the atmospheric spectrum (first described in detail by Langley in 1878 in the Proceedings of the American Academy of Arts and Sciences) that he could account for the remarkable structure of these groups by compounding oppositely rotating spirals of diminishing amplitude which were supposed to give respectively the red and violet components of the pairs of a train. The resultant is an exceedingly elongated ellipse, subject to these perturbations: (1) Decrease of amplitude; (2) diminution of periodic time; (3) slow apsidal motion opposite to the orbital revolution of the electron; (4) a slight fluttering motion like nutation; (5) a further slight secular change in the form of the ellipse. As to whether the spiral is the primary motion and the elliptic relations a concomitant resultant of perturbations, or *vice versa*, may not be easy to determine from the mathematics. The supposition as thus stated by Stoney is somewhat vague, and in spite of appearances of spiral relations in the wave-lengths of a series of lines forming a group, or band in the spectrum, it is not easy to see how such definite wave-lengths can result from a perpetually and *gradually* modified series of spiral circulations. Besides this, the oxygen series relates to atoms in molecular combination, and not to dissociated atoms which give quite a different and much simpler spectrum.

A more reasonable supposition is that of Bohr, of which a slight modification is described by Millikan in *Science*,[3] where it is shown that certain orbits whose

*This paper was presented at the Twenty-first meeting of the American Astronomical Society at Albany, August, 1917 (abstract in Publications of the Society, vol. 3, p. 335), but has been slightly modified since then.

[1] Science, N. S., vol. 12, p. 327, August 31, 1900.

[2] Cohesion between atoms or molecules does not arise from gravitational attraction[fi]l but follows a law of proportionality to the inverse fourth power of the distance, or after the analogy of the gravitational model, is equal to Am_1m_2/r^4. Both Fessenden and Sutherland have shown that this follows as a consequence if we assume the particles to be of the nature of electric doublets. See especially W. Sutherland on The Electric Origin of Molecular Attraction, *Phil. Mag.*, Ser. 6, vol. 17, p. 657-670, May, 1909.

[3] Radiation and Atomic Structure.—Science, N. S., vol. 45, p. 321, April 6., 1917.

radii are in the ratio of the squares of the ordinal numbers are stable, but all intermediate orbits are unstable. When, therefore, the position of an electron is disturbed, it passes explosively to the next stable orbit and may repeat the process several times in succession, each transfer giving rise to an electromagnetic vibration in the period of the new orbit. The number of transfers depends upon the thermal energy available. Under the moderate thermal conditions of our laboratories, often only five members of the Balmer hydrogen series are produced and at most twelve; but in the hottest stars over thirty appear.

In any case, the fact of internal orbital revolution of certain electrons in an atom, presumably the satellite or characteristic electrons, is demonstrated by the Zeeman effect, and by the wonderful agreement in the quantitative values which Millikan has deduced from Moseley's measurements (*op. cit.*). The radiation equation $\frac{1}{2}(mv^2) = h\nu$, where m is the mass of an electron, v its orbital velocity, h = Planck's radiation energy factor, and ν = the vibrational frequency, represents the energy expended in reversing the electric sign, that is, in overturning the axial pose of a particular electron which, although the direction of motion is not changed, is as if the orbital velocity had been reversed. Except for these instantaneous reversals in the generation of light-quanta, the electronic revolutions never cease, for the atom is a form of extraordinary or almost perpetual endurance, and of relatively enormous energy. The agreement of Rydberg's frequency constant N with the value derived from an aplication of Kepler's laws to the electronic orbits constitutes, as Millikan remarks, "most extraordinary justification of the theory of non-radiating electrionic orbits," and verifies at least this much of Bohr's theory.

THE EXTERNAL GRAVITATIONAL POTENTIAL.

It is now evident that every atom consists of two parts: (1) the very circumscribed space in which the above mentioned electronic movements are carried on; and (2) the indefinitely extended field of gravitational potential, or strain, in that universal medium which, following Swedenborg, I shall call the magnetic aura, or simply **the aura.**

The first requisite for any proposed explanation of the facts of gravitation, if it be admitted that a genuine explanation will be of a mechanical nature, is some tentative scheme of a gravitational unit, which shall be capable of generating a longitudinal wave of alternating expansion and compression in the universal magnetic aura. In seeking for such a possible working model, I shall further assume that the aura is divided into complex vortices of galactic dimensions, and that an individual complex vortex constitutes a single independent aural "cell" within which the gravitational motions of its combined masses are confined.

Since all of the motions of the aura are vorticose, this may apply equally to the ultimate direction of propagation of a gravitational wave in the medium. This point may be open to discussion, but is here adopted tentatively on the plea that the electron is probably a polar vertical particle.[4] The wave, therefore, though at first spherical by close approximation, may ultimately pass into and coincide with a complex of magnetic equipotential surfaces, so that the wave-propagation is not radial, save by close approximation at the start, but follows the direction of the curved lines of magnetic force in the field as finally "magnetically" controlled, and thus returns into itself at the point of initiation. This conception has some analogy with Newcomb's idea that space returns into itself through a fourth dimension; but the latter is highly recondite, and indeed transcendental, whereas my proposition is quite simple and is not disproved by any known facts. Newcomb's conception appeals to me strongly as a feasible means of passing through an intermediate from the world of nature to a world of pure spirit which is not in space of three dimensions; and perhaps the full explanation of gravity will require this further extension of rational thought into the region of genuine causes; but for the present this greater problem and border region of science may be omitted.

If the magnetic analogy be accepted, no energy is wasted in maintaining the mechanism of gravitation. Moreover, the elasticity of the aura is almost infinite, so that the velocity of propagation of the gravitational wave is enormously greater than that of light[5]. According to Professor Fessenden's computation,[6] the velocity of the gravitational wave is 5×10^{16} cm. per sec. This is of course simply an inference, but one which rests on reliably known electrical data. Let us suppose that the radius of an aural cell, or the maximum distance to which gravitation is propagated, is 1,000 light-years, which will be near enough for a first approximation to the order of the magnitudes involved. The radius of the vortex is then something like $3 \times (10)^{10}$ light-seconds, or $3 \times (10)^{10} \times v = 9 \times (10)^{20}$ cm., if v is the velocity of light; and a complete circulation along a magnetic line of force which extends to this radial distance will be three times as far, or $2.7 \times (10)^{21}$ cm. Even then, for gravitational wave-impulses which travel along this curve and succeed each other at such rate that a new one does not start until its predecessor has returned, there will be something like two thousand million million waves per second, or a gravitational frequency equal to the radiant frequency in the ultra-violet at $\lambda = 0.15\mu$. Such impulses, therefore, would not be incompatible with the rapidity of known electronic revolutions, assuming that both have the same periodicity.

THE BEARING OF THE SPIRAL GALACTIC FORM UPON THE GRAVITATIONAL PROBLEM.

William Sutherland, in an article on "Bode's Law and Spiral Structure in Nebulae,"[7] concludes that the spirals in Messier 51 *Canum Venaticorum*, M 100 *Comæ*, and M 101 *Ursæ Majoris*, are "approximately logarithmic." The same view is taken by Pahlen,[8] but has been contested by Dr. T. J. J. See in his Researches on the Evolution of the Stellar System (Vol. II) where he says that

"Thus the similarity of figure always breaks down at some point sufficiently clear and well defined to leave no doubt that the spiral cannot be considered, within admissible limits of uncertainty, to be truly equiangular in any one case, and still less is this true of all the different cases where the angles vary so greatly. Consequently the law of attraction operating in the observed spirals cannot agree with that of the inverse cube of the distance, under which alone a particle may describe the Logarithmic Spiral" (p. 55).

And on page 59, after noting that "of all the laws of force which give a zero force at an infinite distance, the Newtonian is the only one for which all the orbits are closed curves," Professor See nevertheless ends with the following statement, which seems to me wholly inadequate and misleading:

"The spiral paths shown in the nebulae, however, are neither closed curves, nor any kind of algebraic curves; because the spirals are often broken, so as to become more or les discontinuous, and markedly irregular. Yet it is not to be inferred from this circumstance that central forces different from gravity are at work among the nebulae. On the contrary, since gravitation is found by observation to govern the motions of the stars, and the nebulae pass by insensible gradations into stellar systems, as is conclusively shown in this volume, it necessarily follows that the central forces operating in the nebulae can be nothing else than universal gravitation; which is a last and sufficient proof that the observed figures of the nebulae are chance spirals, and therefore depart from any kind of geometrical regularity."

If it had simply been said that it is not to be supposed that gravitation is *not* at work in the nebulae, because it is obviously at work in their stellar components, no objection could have been made to such a statement; but when the universally present and peculiar nebular features are ignored and attributed to "chance," and no real attempt is made to explain them, there is urgent need of a different treatment of the data.

It seems to me that Sutherland has supplied the essentials of a correct version. The indications are overwhelming that, while gravitation may not be absent, a different force is in control in these large-scale operations. This force acts according to the inverse *cube* of the distance and is probably magnetic. The law of the logarithmic spiral covers the case well enough. It is not necessary to pin one's faith to some one definite system of logarithms. Sutherland's method picks out that variety of logarithmic spiral which most nearly fits a given case. There are minor deviations which, like the irregularities in comet's tails, point to secondary causes, some of which may be of considerable magnitude; but these do not disprove the continued action of the major force. Thus, for the comet's tail, this force is the pressure of sunlight; and for the spiral nebula it is the magnetic currents of the aura, both of them forces which at first sight seem impalpable, but forces whose power comes from the enormous spaces through which they act.

If it be asked how the currents of the aura can control the motions of the stellar systems, I would answer that the gravitational field is *is* the aura and that, while the energy which is matter is concentrated in material particles, this energy has its complementary reaction which is diffused through an entire sphere of aura. It is, in fact, the interaction of these interpenetrating gravitational fields, each of which extends, if not to the ultimate limits of the aura, still at least within a sphere of aura appertaining to a particular galaxy, which draws the particles together. There is no way of telling whether the gravitational force of a particular galaxy extends to infinity, or only to the boundary of its own sphere of interacting aura, except that which may be inferred from the geometrical structure; but the latter hypothesis, namely, that the sphere of interaction is limited, seems to me the more reasonable one, and we may even suppose that, while there is universal attraction within each aural sphere, the separate spheres mutually repel each other, just as similarly electrified bodies do. In this case the galaxies will be somewhat equably spaced without danger of clashing. The galactic planes, however, lie in every direction without any special preference, or they are apparently wholly independent.

Dr. See assumes that the motion within a spiral nebula is along casual somewhat spiral paths *towards* the center under the attraction of universal gravitation. A. Van Maanen, on the contrary, finds in his research described in the Astrophysical Journal for November, 1916,[9] "Preliminary Evidence of Internal Motion in the Spiral Nebula Messier 101," that the motion is *outward*."[10] He also finds evidence of rotation; but whereas, under the gravitational attraction of a massive central nucleus, orbital motions at radial distances of 2.′2 and 8.′9 should be in the ratio of the inverse squares of the distances, or as 16 to 1, Van Maanen obtains:

At mean distance 2.′2, rotational component = 0.″024.
At mean distance 8.′9, rotational component = 0.″019,

or very nearly the same curved-line speed at both points, and along the paths of the spirals; that is to say, the nebula rotates not as if it were in one piece, but as if there were also uniform stream-motion along the radius away from the center; whence I infer that the motion which we see is not that of matter under gravitational attraction, but is controlled by the motion of a vortex in the aura within which the stellar groups are carried along like dust motes in an air whirl. If the motion had been uniform along *circular* paths around a common center, we might attribute them to a discoidal aggregate revolving under the influence of the mutual gravitational attraction of the parts; but this does not seem to be the case. Since it is obvious that the outward motion cannot continue indefinitely without dissipation of the group, and since there is some evidence of deviation from any single logarithmically spiral mode, the velocity is probably not strictly uniform, and the shape probably changes eventually, either by the formation of side branches and diversion into feathery plumes, or by expansion into an annulus.

The globular clusters are probably under gravitational control, and a slight vorticity, indicated by a few obvious lines of stars arranged in spiral order, with a very small ellipticity, or tendency to a discoidal shape,[11] are the only evidences of even a remnant of activity of aural currents. Here the currents certainly seem to be subordinate,[12] but in the white nebulae they have control.

If Van Maanen's determination of a radial expansion of 0.″007 per year in Messier 101 is genuine, only 42,000 years would be needed to expand to a radius of 5.′. Such rapid motion would imply a small and relatively near object. A difficulty immediately appears, for Van Maanen makes the period of rotation 85,000 years, and if this corresponds to a real rotational velocity of 260 km./sec. (*op. cit.*, p. 224), such a motion, if due to gravity, would mean that the radius of 5′ is equal to 750,000 astronomical units, parallax = 0.″0004, mass = 57,812,500 × sun's mass. The rotation, if due to gravity, would require a much greater stellar condensation than that of our Galaxy. The supposition of an aural vortex would remove the difficulty and would permit us to place the nebula at a much greater distance, giving it linear dimensions more nearly comparable with those of our own Galaxy. The extraordinarily rapid expansion must represent a temporary stage of development, to be succeeded by slower expansion to a final permanent form and quiescence.

CONCLUSION.

The conclusion reached is that the gravitational vibrations are probably confined within definite volumes of a universal medium, or magnetic aura, and are limited outwardly by the form, motion and peculiar properties of this medium which exercises a general control on all gravitative phenomena; so that the larger galaxies resemble discrete organisms, or perhaps a better comparison would be that of discrete and independent, but intimately related cells of one great organism; while the inner limit and origin of the gravitational vibration appears to reside in the pulsating surface of the electronic vortex-ring, or least gravitative unit.

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[4] In another paper ("The Luminiferous Ether," Occasional Scientific Papers of the Westwood Astrophysical Observatory, No. 2, p. 36) I have suggested that the electron itself probably has an internal vorticose motion and polar structure which adapt it to the required function even in its pulsations. But the electronic complex, the atom, is always a perfect sphere.

[5] Thomson's (Lord Kelvin's) discussion of a mathematical proposition by Green, in the course of which he arrived at the conclusion that the velocity of gravitation (contrary to the almost universal opinion of astronomers) cannot be large, may be placed alongside of his opinion that "it is absolutely impossible to conceive of the currents which he [Ampère] describes round the molecules of matter, as having a physical existence" (Papers on Electrostatics and Magnetism, p. 469). The currents of electronic revolution around the atoms are now thoroughly established, in spite of Lord Kelvin.

[6] R. A. Fessenden, A Determination of the Nature and Velocity of Gravitation, Science, N. S., vol. 12, p. 744, November 16, 1900.

[7] Astrophysical Journal, vol. 34, pp. 251-260, Oct. 1911.

[8] Astronomische Nachrichten, Nr. 4503.

[9] Vol. 44, pp. 210-228.

[10] For other facts which indicate that development of stellar systems is expansive, rather than concentrative, reference may be made to the author's paper: A Cosmic Cycle, this Journal, vol. 13, pp. 47-58, 97-114, 185-196.

[11] See Francis G. Pease and Harlow Shapley, On the Distribution of Stars in Twelve Globular Clusters, Astrophysical Journal, vol. 45, p. 225, May, 1917. So slight is the ellipticity in M 13 that it was best brought out by arranging the stars on a basis of color-index or variability (p.229).

[12] The velocities also of the globular clusters, as determined by Silpher, are smaller than those of the spiral nebulae.

Insects in Their Relation to Forestry*

Some Interesting Larvae That Prey Upon Our Trees

By Dr. R. W. Shufeldt, F.A.O.U., Etc.

(Photographs by the Author)

For the past half century and more, the immense host of insects that are, to a greater or less degree, inimical to our forest, fruit, and shade trees, have been under investigation by entomologists in both public and private life. The indefatigable workers in the various Federal departments at Washington and elsewhere have contributed an enormous literature to this subject, covering every line of research embodied in the science; while the results they have achieved have been of the most incalculable value, not only to the country at large, but to those interested in trees of all kinds anywhere. This is true irrespective as to whether the latter be represented by our most extensive private or governmental forest owners, or by one having but a few trees under his care in any part of the United States, or in neighboring countries, whereon such insects occur.

As stated above, a large part of this literature, referring to the various forest-insect problems, has been published by the Government, and particularly by the Bureau of Entomology of the United States Department of Agriculture, of which Dr. L. O. Howard is the Chief. While a fairly generous supply of these bulletins and other publications are issued, they by no means reach all they should, nor supply the demand for them by those interested in the subject at large. This being the case any extension of the knowledge of such matters, in any of its departments, should be regarded with favor. In this work the bulletins issued by the Forest Insect Investigations of the Bureau of Entomology, of which Dr. A. D. Hopkins is in charge, have been especially helpful, while in addition to such aid a great many actual observations, extending over many years, have been made by the present contributor in the fields and forests. The observed phenomena thus studied will all be incorporated as the material is worked up and illustrated. Almost without exception the photographs of the matter described have been made from such material; and where certain insects have not been easily obtainable, they have been generously loaned the writer from the duplicate series in the United States National Museum collections. For such courtesies thanks are especially due to Drs. E. A. Schwarz and Harrison Dyar; to Messrs. Carl Heinrich, J. C. Crawford, H. S. Barber, and to others associated with them in the Bureau.

From the various sources of information brought down to us from the earliest time to the present day, certain primary facts have been established. In the first place, the list of insect forms that attack *forest trees* in this country is not an especially long one, when we come to consider the enormous array of species that are entirely innocent with respect to any such charge. Many insects attack trees that have no claim to be classed as forest trees; while a formidable list of insects commit their depredations upon certain shrubs and plants, and never have anything whatever to do with trees. There are insects that feed only upon the *leaves* of forest and shade trees, causing damage to that extent alone; some of the bark beetles devote their attention to fully grown and sound trees, while other species do so wholly to dead or dying ones, or to fallen trunks of them in the forests and elsewhere. Then the roots of forest trees also have their special enemies, while others destroy the bark.

In so far as forest trees are concerned, perhaps the most destructive insects are the bark beetles, of which there are quite a large number of species. These beetles have, in times past, utterly destroyed forest trees covering hundreds of square miles, and they are committing the same depredations at the present time. They bore through the bark of pine, spruce, hickory, fir, and other trees—full-grown, healthy trees—and subsequently completely girdle their main trunks, which ultimately kills the tree so preyed upon.

In passing through the vast pine forests of the Southern States, as the writer has frequently done, one may plainly see the fearful devastation wrought by the various invasions of the common pine beetle of the South. Hundreds of square miles of dead pine and spruce trees may be seen in various stages of decay, the death having been caused by this pest. We may even observe the same class of destruction in its various stages in certain areas within the District of Columbia. Great quantities of useful timber have thus been lost to the country and the industries; while we may note similar destructive work in progress, and at all stages, due to the operations of the spruce beetle in the forests of those trees in northeastern United States and southeastern Canada. "This species," says Doctor Hopkins, "caused the death of a very large percentage of the mature spruce over an area of thousands of square miles. In the aggregate many billions of feet of the best timber were destroyed. The large areas of this dead timber furnished fuel for devastating forest fires, with the result that in most cases there was a total loss."

Passing from these few introductory remarks on forest beetles to moths, we enter upon one of the most attractive fields of inquiry and observation in the entire realm of biology. As in the case of all the biological sciences, it has its large literature, illustrated by thousands upon thousands of plain and exquisitely colored figures; while upon the other hand there is the entire world of nature ever standing open to the investigator for the verification of all that is set forth in that literature, and offering at the same time no end of new material for study and description. All this is equally true of the butterflies—a group so closely allied to the moths that they appear almost to run into each other. Now, in a great many instances, the larvæ or caterpillars of both moths and butterflies feed upon the leaves of trees of many descriptions, those of our forests as well as the shade trees of our towns and cities. These insects may be studied with a great many objects in view; but this field is so extensive that to enter upon it in any satisfactory manner would result in the presentation of material far exceeding the limitations of the space at our command in the present connection. However, right here it is proposed briefly to introduce one of the very handsomest moths in our insect fauna. This is the Regal or Royal Walnut moth, *Citheronia regalis* of Fabricius. Its caterpillar is a most remarkable looking creature. A summer or two ago, Mrs. Bert S. Elliott, of Washington, D. C, was good enough to furnish me with more than a dozen living specimens of this grand larva of our Regal moth, they being transported on a big limb of a sycamore tree, bearing a great quantity of fresh leaves, which latter constitutes one of their foods in nature. In a reproduced photograph, this caterpillar is a rather tame-looking affair as compared with the living animal. To appreciate this, one must indeed see it in life, with its shiny, pea-green body, ornamented on the sides by an interrupted series of black and white markings; its red head and tail-plates; red and black feet, and its remarkable, double pair of curved, red and black horns on the segments just back of the head. Smaller horns, too, are seen elsewhere on the body, as shown in the cut. Country boys call this caterpillar the "Hickory Horn-devil," and generally destroy it upon discovery. It has an average length of some five and a half inches, and is the largest caterpillar in our insect fauna. It does not spin a cocoon, as many other large caterpillars do; on the other hand, sometime in September, it works its way under the ground, there to be transformed into the pupa (Fig. 2), from which it emerges during the following July as an elegant orange-red moth, with the dainty white and yellow markings here seen in Figs. 2 and 3.

This caterpillar feeds upon the leaves of the butternut, hickory, persimmon, sumach (*Rhus*), sycamore, and walnut trees. Of the last-named we have a victim in Fig. 4. This moth is rare in the North and nowhere abundant; while in the State of Georgia it is said to be double-brooded. In this genus *Citheronia* we have at least two more species of these big moths, namely the "Pine-devil moth" (*C. sepulchralis*) and the Mexican Walnut moth (*C. mexicana*). Of the former Doctor Holland says: "It ranges from the Carolinas northward to Massachusetts along the coast. It is not common in the valley of the Potomac, and at Berkeley Springs I have found it abundant in the larval state in the months of July and August."

The third species is found in Arizona and northwestern Mexico. To rear and study this elegant moth—indeed, any of our large moths—one has but to place the larvæ or caterpillars in a large and thoroughly clean pine box containing about a foot or more of soft, dark soil. The top should have a fine wire-mesh cover that can be readily removed. Fresh leaves of the sycamore or other trees mentioned above should be fed to them every day and the unconsumed ones removed. After all the larvæ have disappeared under ground, the box may be kept in a dry and moderately warm room until the following summer, when your

Fig. 1. The larva or caterpillar of the regal moth
(*Citheronia regalis*)

This elegant larva of the Regal or Royal Walnut Moth is of an intense green color, with black and white markings. Its curious pairs of "horns" are brilliant scarlet, tipped with black. It is seen here feeding on the leaves of the sycamore tree.

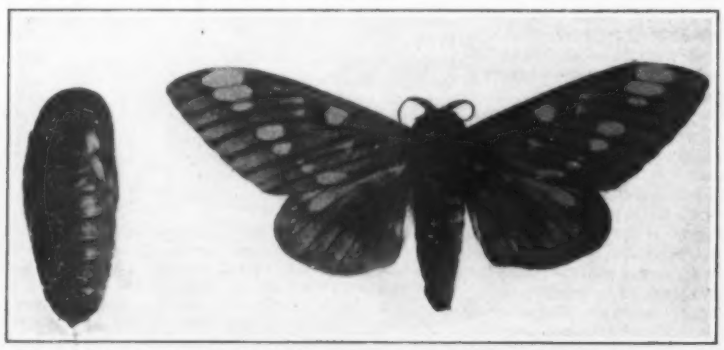


Fig. 2. Male regal moth, viewed from above. Specimen in the collection of the United States National Museum. The dark brown pupa is shown to the left. Both reduced about one third

Here is an instance in the insect world where the male of the species is conspicuously smaller than its mate (see Fig. 3).

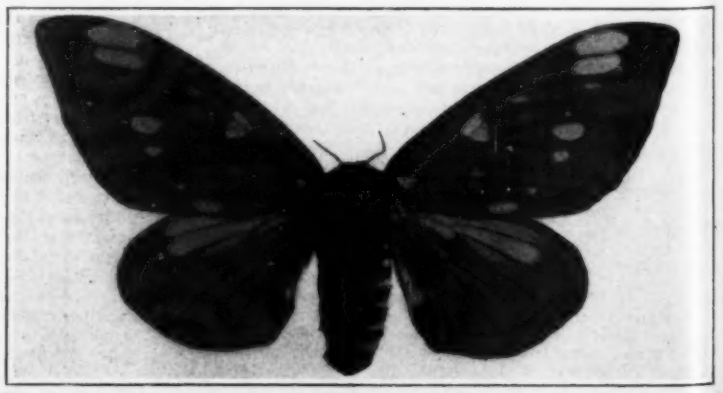


Fig. 3. A perfect specimen of a female of our regal walnut moth; natural size, and viewed from above

This well shows how carefully these moths are mounted in our great collection in the National Museum. In coloration, this is a very striking species, hence its name, "Regal."

*Reproduced by courtesy of *American Forestry*.

moths will be forthcoming—and what superb creatures they are upon emergence!

Butterfly larvæ, of a great many species, genera, and families, also feed upon the leaves of various trees of the forest, and among them we find not a few representatives of the genus *Papilio*, which is a truly gorgeous assemblage of forms; they may be reared from their chrysalids in the manner recommended in the last paragraph in the case of moths.

A few miles west of Washington, along the old Georgetown Canal, is a great place to meet with the Ajax Swallowtail—a butterfly of extreme beauty (Figs. 5 and 6). There is a good reason for finding the insect in that locality, as in the marshy area between the towpath and the Potomac flourish many Papaw trees (*Asimina triloba*), and it is upon the leaves of these that the caterpillars of the various forms of this butterfly feed. On one occasion, in this locality, the writer captured three of these butterflies with one sweep of the net, as they rested on the mud within a few feet of the Potomac. Upon reversing the net, two were taken and one escaped. Doctor Holland gives us a beautiful colored plate of these zebra butterflies in his "Butterfly Book," upon which five different subspecies of *ajax* are shown, as well as *Papilio eurymeda* of the same group, the one shown in Fig. 5 of the present article being *Papilio ajax marcellus*—male. *Walshi* is the winter form of *ajax*, the "chrysalids which have been exposed to the cold of the winter" produce it; "the black bands of the wings are narrower and a trifle paler than in the other forms, the tails of the hind wings tipped with white, and the crimson spot on the inner margin near the anal angle forming a conspicuous bent bar." In flight, this butterfly has the appearance of being white, banded with black (as in the cut for the under side), with the wings emarginated with a broad band of black; the red spot is quite conspicuous. It would seem that in certain localities these various types of *Papilio ajax* intergrade, making it a bit difficult sometimes to define and name them with absolute certainty. In any event, as it does a tree no good to have its leaves eaten up by caterpillars, and as the Papaw is a tree of some value along the streams that course through our forests, the caterpillar of this handsome butterfly must be considered in the light of an insect inimical to it.

Speaking of the early stages of the genus *Papilio*, Holland says that "the eggs are somewhat globular, flattened at the base, and smooth. The caterpillars are cylindrical, smooth, fleshy, thicker in the anterior portion of the body than in the posterior portion, and are always provided with osmateria, or protrusive scent-organs, which, when the larva is alarmed, are thrust forth, and emit a musky odor, not highly disagreeable to the human nostrils, but evidently intended to deter other creatures from attacking them. The chrysalids are always attached by a button of silk at the anal extremity, and held in place by a girdle of silk about the middle. The chrysalids are, however, never closely appressed to the surface upon which pupation takes place."

It is surely very remarkable how the caterpillar can attach the delicate little girdle of silk that goes about its waist, or the "button" at its abdominal extremity, during the transformation performed through pupation. It has not been the writer's fortune to observe this up to the present time, notwithstanding the fact that many pallilionian larvæ have been kept by him during their transformation to the pupa stage, and, after that, until the butterflies emerge from them. The suspending girdle is invariably adjusted with the greatest care,

Fig. 5. Few butterflies in eastern United States can rival in beauty the famous "swallowtails;" and of all that group there is not a handsomer species than the one here shown, which is widely known as the "zebra swallowtail"

Butterflies of this zebra kind long puzzled the entomologists, for the reason that they were found to be seasonally polymorphic. The one here shown is the Ajax—a most remarkable insect.

Fig. 4. [One of the oldest black walnut trees in the environs of Washington, and one that has probably seen fifty summers come and go

Trees succumb from all sorts of causes. Old age has overtaken this one; but it has also been struck by lightning; partly strangled by vines; furnished food for thousands of larvæ, and weathered the gales of half a century.

in the same place, with the head of the pupa above, and the very firm fastening of the tip of the abdomen below. This, it will be seen, holds the pupa in such a way that the median longitudinal line of its body makes an acute angle with the plane of the surface to which it is attached.

Thus hangs the pupa of a *Papilio!* But why it should apparently be obliged to be suspended in that manner, while the pupa of an *Argynnis*—such as one of our Silver-spots for example—should only be suspended by the end of the abdomen, is surely difficult to explain.

As has already been noted in a previous paragraph, the larvæ or caterpillars of our moths and butterflies feed upon the leaves of trees; but the beetles, upon the other hand, are far more destructive, for, as a rule, they attack the bark, the true wood within, and the roots. An excellent example of such insects is seen in the Broad-necked Prionus (*Prionus laticollis*) of Drury. In Packard's report on Forest Insects we find a cut of this species, with figures showing the larva and pupa, after Riley. The beetle is shown in the accompanying illustration, Fig. 6, which is from life. Generally this insect is discovered living in the trunks and roots of the trees known as the Balm-of-Gilead and the poplar; but Mr. F. Clarkson found, many years ago, specimens of this borer infesting the Black oak. He reported in the *Canadian Entomologist* (XVI, '95) that "their presence is quickly realized by the odor of the female, which is very powerful, and can readily be detected 20 feet distant. I placed a female, immediately after emergence, in an uncovered jar; and wherever I positioned it, on the piazza or elsewhere, the males were attracted from every direction. I captured twenty males in a very few minutes. Oak Hill cannot boast of a Balm-of-Gilead or a Lombardy poplar, but it is famous for its oaks; and while it is admitted that the former trees as mentioned by Harris, serve as food for the larvæ, my observations indisputably prove that they feed also upon the roots of the oak."

This beetle is of a blackish brown color, shiny, and exhibits no markings whatever. It is a strong flyer; and when on the ground it gets along with considerable rapidity, especially when not impeded by the vegetation or the coarse, pebbly character of the ground or soil. Frequently they make their appearance in the streets of our towns and cities at night, apparently attracted by the lights in the streets and windows of our dwellings. This Prionus is a hard, strong beetle, requiring a pretty stiff blow to crush it. Its jointed antennæ are of a fair length only, though stout and beautifully jointed with short joints. When at rest, each one exhibits a gentle curve outwards and somewhat backwards. Its eyes are rather large, while one of its most striking characters is the unusual width of its neck, which, upon either outer margin, presents a pair of pointed processes, one in the middle and one occupying the supero-external angle. Its outer wings or elytræ are granulated, and so rather roughish; while mesially, the ultimate segment of the abdomen projects beyond them. Finally, we may say that its three pairs of legs, having the same color as the rest of the insect, are rather stout, but otherwise in due proportion to the size of the insect.

Low-Voltage Arcs in the Vapors of Hg, Na and K

T. C. Hebb describes experiments on the ionisation potentials of Hg, Na, and K, with special reference to the production of low-voltage arcs in these vapors. It is shown that potassium vapor can be ionised at 1.6 volts, which is its resonance voltage, and that sodium vapor can be ionised at 2.5 volts, which is very close to the reconance voltage. This result agrees with that found by Wood and Okano. It was found that the D-lines of sodium can be excited at less than 1.0 volt; also in agreement with Wood and Okano. Sodium and potassium arcs in mercury vapor can operate below their resonance potentials, and as low as 1.4 volts for Na and 0.5 volt for K.—*Sci. Abstr.*

The Value of Lupins in the Cultivation of Poor, Light Land*

Lupins grow with remarkable luxuriance on very light land, poor in lime. At the present time, owing to economic conditions, there is grave danger that considerable areas of this type of land will go out of cultivation. It would appear that an extended growth of lupins offers one of the simplest methods of rendering economically possible the cultivation of this land, and possibly of reclaiming what is already derelict.

Owing to their deep-rooting habit, and their powers of assimilating the free nitrogen of the air, lupins greatly enrich the soil, and whether ploughed in green, folded with sheep, or harvested for seed, leave a considerable quantity of residue upon the ground, which is of great value to the succeeding crop. Very heavy crops of rye are being grown this year after lupins, on land actually adjoining the heath.

When folding care must be taken not to allow the sheep to eat too much or they will suffer from paralysis owing to lupin poisoning. Suffolk flockmasters fold their sheep on lupins with confidence, and do not regard the risk as serious. Sheep take some time to get accustomed to the bitter flavor of lupins, but thrive remarkably well once they have become used to them. They cannot live satisfactorily on lupins alone, but must have access to other food.

There is often some difficulty in disposing of lupin seed, owing to the fact that it contains some poisonous substance, and is very bitter. In Suffolk lupin grain is fed to sheep at a rate not exceeding half-a-bushel per day per 100 sheep, and the feeding must commence gradually. If too much is fed the sheep become paralyzed. It is claimed in Holland that a method has been discovered whereby the poisonous principle can be extracted, and the grain rendered fit for stock-feeding purposes. If this could be done it would give a great stimulus to lupin-growing, and would be a considerable advantage to light-land farmers, as lupins might then occupy the same place on light land as is occupied by beans on heavy land.

*Abstract of a paper read before the Agricultural Section of the British Association by A. W. Oldershaw, M.B.E., B.Sc.

Fig. 6. We have here an enemy of the black oak—a beetle known as the broad-necked prionus

(*Prionus laticollis*)

During the first two weeks in July, this big, black Prionus emerges at twilight, and may frequently be captured around the street-lights of eastern cities. This is a Washington specimen.

The Static Head Turn Indicator for Aeroplanes*

An Instrument Which Enables an Aviator to Find His Way in a Fog

By Sir Horace Darwin, K.B.E., F.R.S.

An instrument to indicate whether, under all conditions, the path of the aeroplane is a straight line or whether it is turning to the right or left is much required. It is well known that when flying in a cloud or at night, and no fixed object is visible, even the most experienced pilot may, without realizing it, be flying on a sharp curve. If, however, the angle of banking is great the muscular reaction of his body will have to be increased to counteract the increased force acting on it. This will tell him that his course is not straight, but there is nothing to show whether he is on a right-hand or left-hand turn. If he tries to straighten his course he is just as likely to increase the curvature as to straighten out. If he observes his compass he will probably find that it is swinging so much that it will tell him something is wrong, but give no guide to what he should do.

A turn indicator permits a straight compass course to be kept when flying in clouds or at night, and this is valuable for long-distance flights. But straight flying is always important. If the clouds are low and the aeroplane leaves their lower surface when on a sharp turn there may not be sufficient time to allow the machine to be put into a safe position for landing before the ground is reached.

The late Captain Lucas, D.Sc., F.R.S., proved that when flying in a northerly direction the compass turned with the aeroplane, and when flying in a southerly direction the opposite took place. Before he investigated the subject at the Royal Aircraft Establishment all that was known was that the compass became unreliable in cloud flying; he found what the facts were; discovered the cause of the behavior of the compass and designed and made a compass which was a very great improvement on the compass then in use, although it did not completely overcome the difficulty. This scientific achievement was of the greatest value to the flying service. It was when doing such work as this that he was killed, and the country lost a brilliant scientific man.

In June, 1912, a memorandum by Mr. C. C. Mason and myself was submitted to the Advisory Committee for Aeronautics. In it the principle of the static head turn indicator was explained. At a later date Dr. Lucas tried some experiments with the manometer supplied by me, a very different one from that now made by the British Wright Co. This manometer was crude and bad in principle, and broke down after a short trial, but showed some promise. The experiments were not continued owing to press of other work, and because I think even he did not then realize the value of a satisfactory turn indicator, and I certainly did not.

The object in view at that time was to obtain the true vertical for bomb dropping. Major Dobson tried some interesting experiments at Upavon with very simple apparatus. Later I made an elaborate instrument which was probably too difficult to manipulate.

Very many attempts have been made to make instruments which would show the true vertical when flying in a circle. If a pendulum hanging from a support on an aeroplane would always point in the true vertical direction it would be easy to make an instrument which would show whether the wings were level. But it is well known that this is not the case; on a truly banked turn the pendulum will remain at right angles to the plane of the wings, and the pendulum will only show whether the aeroplane is under or over banked. Many inventors have suggested pendulums, or their equivalents, such as a level, or bubbles rising through a vessel containing a liquid, or a flame which points vertically upwards. Very few of the inventors of these instruments realized the fundamental difficulty, and those few who did, failed to overcome it.

Another possible method is to make use of the fact that on a turn the apparent attraction of gravity is increased. The index of an ordinary spring balance supporting a weight would move when on a banked turn, and show a greater weight than when flying straight. In this case a left and right turn would have the same effect. Also the indication would be very small for turns of large radius. The vertical acceleration, especially on bumpy days, would have a far greater effect than even sharp turns.

It has also been proposed to measure the banking angle by an electrometer giving the difference of the electro-static potential at the wing tips. This method was, however, not found to be a success.

Successful turn indicators using gyroscopes have been made.

We will now describe the static head turn indicator.[1] In conjunction with a good aeroplane compass and a cross level, a true compass course can be kept in clouds or at night. The success of this instrument is due to the large amount of experimental work done at Orfordness and at the Royal Aircraft Establishment, and to the design of the Ogilvie pressure gauge manufactured by the British Wright Co. Unless a pressure gauge as good and as sensitive as this instrument had been designed, the turn indicator would not have been a success.

A great number of experiments had to be tried in order to determine the best position for fixing the static heads, on the relative advantages of fixed and swivelling static heads, and on the effect of side-slip.

A sensitive differential manometer is fixed on the instrument board, and the Ogilvie pressure gauge is used for this purpose. The two openings from it are connected to two static heads, fixed to the wings as far apart as can conveniently be arranged, and in a position so that the air pressure at these points is influenced as little as possible by the wings or body of the aeroplane. The manometer will then indicate a difference of pressure when the aeroplane is turning. The hand will move in one direction for a turn to the right and in the other direction for a turn to the left.

The pressure gauge was designed by the British Wright Co. for use with the turn indicator, and is of the Ogilvie type. An extremely sensitive circular rubber diaphragm separates two chambers in the instrument. These chambers are connected, one to each static head, and the minute difference of pressures caused by the aeroplane turning deflects the diaphragm by a small amount. The deflection is communicated directly by a silk thread, without intermediate gear, to the indicating hand and moves it to the right or the left. The scale carrying the zero mark and divisions is adjustable by the pilot during flight by the use of one thumb, and he can easily set the scale in the correct position when flying on a straight course immediately after leaving the ground. This adjustment is most desirable, as it is found that the position of the hand when on a straight course does not correspond with absolute equality of pressure on the two sides of the diaphragm.

This is due both because it is impossible to make both static heads absolutely similar, and also because the actual static pressure at the two positions where the static heads are fixed are not equal. No doubt if it were possible to fix the static heads at a great distance in front of the wings the amount of adjustment required would be greatly reduced. The adjustment required is seldom more than 10°.

The air inside the static openings is very nearly the true air pressure outside in a well-designed static opening. The static heads used are the same in form as those used in the standard air-speed indicator. The tube moves through the air in the direction of its axis; the stream-line end of the tube disturbs the air as little as possible, and thus the air passes over the holes in the side of the tube at right angles to their direction. It had been found by experiment that the air pressure inside the tube is very nearly the true pressure outside, whatever the velocity the tube moves through the air may be.

A great authority on birds tells me that he has no doubt that birds breathe through their nostrils. He might find it difficult to actually prove this, but it is very unlikely that he is not correct. It is an interesting fact that the nostrils of birds fulfil to some extent the conditions of a well-designed static opening; the nostrils are holes in the beak, and in flight the beak moves through the air point forwards. It is clear that this arrangement is advantageous to the bird. To ensure ease in breathing, the air inside the lungs should be at the same pressure as the air outside. I do not know whether men in aeroplanes find any difficulty in breathing when the head is in the wind. If they do, no doubt the difficulty could be reduced by breathing through properly constructed static openings.

Experiments were tried with fixed static heads, as it was hoped that the swivelling form was not necessary. They were fixed to the struts between the wings, but in this position side-slipping had a considerable effect; in some cases this was so great that the index of the pressure gauge showed a right-hand turn when a left-hand turn was taken. The fixed static heads were then placed in front and above the leading edge of the upper wing. In this position the results were much better, but the heads must be truly parallel. In this exposed position it was found that they were liable to become accidentally displaced, and as this might easily happen without the pilot knowing it, then the instrument would not be trustworthy. When swivelling heads are used and placed in the standard position, the effect of side-slip is greatly reduced, and turns to the right or left are correctly indicated. To eliminate all effect of side-slip the static heads must be put inconveniently far from the wings.

The swivelling static heads are required to adjust their angle with the greatest freedom. They are carried by swivelling bearings allowing universal movement, and fixed to rigid standards. The air is always free to flow by way of a rubber tube which twists to accommodate the adjustment of the head to right and left, and bends to permit of inclination up and down. The static head thus free to move in all directions, is maintained parallel to the direction of the wind by means of a conical vane. Its weight has no tendency to move it out of the true direction as it is carefully balanced about its swivelling bearings.

It was also found important to avoid sharp bends or constrictions in the tube, as otherwise the indication on the dial was sluggish. The air tube on the static head openings becoming blocked with ice is a possible cause of failure.

Some of the earlier experiments were made with venturi tubes instead of static openings at the ends of the air tube. This will reduce the air pressure at both the outer ends of the air tube, and it will reduce it most at the end which is moving fastest through the air. When flying in a circle, the outer wing tip is moving faster than the inner wing tip, and the air in the air tube will be drawn outwards, and this will cause a pressure on the manometer. This pressure will be in the same direction as the pressure caused by the centrifugal force, and the two pressures will be added together and the effect will be greater than when static heads are used. The result is that the pressure on the manometer is increased, and this is an advantage.

This arrangement was tried, but the readings on the manometer were found to be much more unsteady, and for this reason the instrument was less satisfactory than when static heads were used.

Major G. I. Taylor has investigated the question of gusts and eddies in the air. In a gust the static pressure as well as the velocity vary. When static heads are used the change of velocity has no effect on the air pressure in the air tube, and unsteadiness of the manometer readings is only caused by the variation in the pressure. With venturi tubes, both the variation of velocity and pressure will cause unsteadiness. It has been found that the fluctuations in static pressure due to gusts are of the order of $pu^2/2$, where u is the fluctuation of the velocity in the gust. The velocity of the gust may increase or diminish the velocity of the venturi tube through the air, depending on the direction of the gust; and may even have opposite effects on the ends of the air tube, increasing the velocity at one end and diminishing it at the other.

If the velocity of the venturi tube through the air is v and a gust of velocity u meets it, then the velocity through the air becomes $v + u$. The reduction of pressure in a venturi tube is approximately proportional to the square of the velocity of the air. The reduction of pressure is $\frac{1}{2}\rho\ [(v + u)^2]$ or $\rho v\ u$ as u is small compared to v. With a quick-flying aeroplane v is very large, and the reduction of pressure will be by no means small even if the velocity of the gust is very small, and we should expect the pointer of the manometer to be unsteady.

It follows from the foregoing that we should expect this unsteadiness to be from 10 to 20 times as great with venturi tubes as with the static heads, and this has been verified by tests in the air.

Small differences of pressure have to be measured, and as venturi tubes are very sensitive to change of shape, it would also be very difficult to make them sufficiently alike.

It is found also that in actual practice a venturi tube gives an unsteady suction even in a uniform wind. This is probably caused by the flow of the air through the venturi tube becoming unstable at some velocities. Pitot tubes for this reason also, are better than venturi tubes.

A manometer has been made sufficiently sensitive to indicate turns of large radius, and as steadiness of the readings is of very great importance, it is far better to use static heads than venturi tubes.

In order to make the action clear, we will assume that the aeroplane is moving in a circle, that it is not banked, and that the air tube connecting the static heads is horizontal and points along a radius of the circle. The forces acting on the air in this tube are:

1. Gravity acting vertically downwards. As the tube is horizontal this will cause no difference of pressure at the manometer or cause any tendency of the air to move along the tube.

2. The atmospheric pressure at the static heads. As the tube is horizontal the pressures at the ends of the tube are equal and in opposite directions, and no effect is produced on the manometer.

3. The pressure of the inner surface of the tube against the air; this clearly has no effect on the manometer.

4. Centrifugal force is the one remaining force which can cause a movement of the differential manometer. The air will tend to move along the tube in an outward direction and can only be prevented from so doing by a difference of pressure on the two sides of the dia-

*Paper read before the Royal Aeronautical Society at the Royal Society of Arts, October 29, 1919.

[1]Secret Patent (applied for March 20, 1918) was taken out for this invention. The Patent No. 123,996 was published on April 10, 1919. In the Service it is known as the "Aero Turn Indicator with Mark I and Mark II Static Heads."

phragms in the manometer. It is this difference of pressure which is indicated on the manometer and shows a right- or left-hand turn.

All turns, however, are banked, and this assumption is only made to make the action clear.

Let us now consider a banked turn and assume that the aeroplane is banked at the correct angle. By the correct angle is meant an angle which causes no side-slip; that is such an angle that the apparent direction of gravity (that is the resultant of gravity and centrifugal force) is at right angles to the plane of the wings.

Again consider the forces acting on the air in the tube.

1. As the banking is at the correct angle, the resultant of gravity and centrifugal force act at right angles to the direction of the tube and have no effect.

2. The pressure against the inside of the tube clearly has no effect.

3. The atmospheric pressure at the two static heads is not equal; as the aeroplane is banked, the outer end is higher up and at a place where the air is at a less pressure. The differential manometer will show this difference of pressure.

Or we can consider this last case differently. The forces acting on the air in the tube are:

1. Gravity acting on the air in the tube. As the tube is banked this will tend to make the air flow inwards.

2. Atmospheric pressure at the static heads. As the pressure at the outer end is less than at the inner end these pressures will tend to make the air flow outwards. The tendency of (1) and (2) are obviously equal and in opposite directions, and the combination of the two will have no effect.

3. The pressure against the inside of the tube clearly has no effect.

4. Centrifugal force is the only remaining force, and this clearly will cause a difference of pressure on the two sides of the diaphragm of the manometer. Although these two ways of considering the forces which act on the air in the tube are so different they are both correct.

If V = the speed of the aeroplane.
r = radius of the circle in which it is flying.
b = the distance between the static heads.
ρ = the density of the air.
P = the differential pressure on the air required to prevent its movement along the air tube.
β = the angle of banking.

With horizontal flight, no side-clip and the air tube in the vertical plane passing through the center of the circle.

$$P = r^2 \cdot b \cos \beta / r$$

Usually β is the correct banking angle, then $\tan B = v^2 / gr$: In order to make P large, b must be large. As the density of the air becomes less with increased height the indications will also become less.

The instrument can only be used for measuring r if we know the speed and the density of the air, but it is not wanted for this, and is only useful for showing that the aeroplane is turning to the right or the left.

If an aeroplane is flying near the ground at 80 m.p.h. in a circle of one mile radius, a complete circle would be flown in 4½ mins., and the correct banking angle would be 4°—40′. If the static heads are 30 ft. apart the air pressure in the manometer would be about 1 mm. head of water when flying near the ground. This pressure will move the head on the dial through about 14° or about 1½ divisions, and the turn will be clearly shown. If the height of the aeroplane is so great that the density of the air is reduced to half its normal amount the indication will also be reduced to one-half.

The turn indicator has been tried on many different types of aeroplanes. The following are some extracts from a report which we have been kindly allowed to see and quote:

"In connection with the daily cloud and horizon observations, it has been necessary to attempt to fly through thick layers of cloud. This has been tried on several types of scouts, and after considerable practice it was found possible to get through several thousand feet of solid cloud, but it required very rigid concentration on the control of the machine, even then it frequently got out of control, and after losing height, climbing had to begin again. It was practically impossible to have any sense of direction during a long climb in cloud. Layers of cloud of various thicknesses up to 6,000 ft. were got through, but it was decidedly unpleasant flying."

The turn indicator was then fixed to a 110-h.p. Le Rhone Camel, a difficult scout to fly through clouds. The first position of the static heads was not found satisfactory. A second position was tried. The report goes on:

"Although not extremely sensitive, it was most useful, enabling the machine to be flown in comfort for a considerable time in clouds. . . . As compared with the experience in clouds on scouts without turn indicators, flying in clouds was now quite pleasant, as the machine never showed any sign of getting out of control. To fly straight was quite easy, keeping a fairly reasonable compass course, to make a gentle spiral up or down, or a very steep spiral. . . .

"The static heads were only tried in two positions, but it may be that a position could be found without their being unreasonably far in front of the plane, so that the indicator would be more sensitive.

"It would need some considerable practice before the average pilot could take a Camel, or most scouts through much cloud, but it makes cloud flying on scouts possible, whereas without turn indicators it is practically impossible."

Electrical Phenomena in the Upper Atmosphere

(*Continued from our issue of September 27, page 202. Publication delayed by the strike of pressmen and compositors.*)

14. Two further points which arise for consideration relate to the circumstances of the corpuscular emission from the sun, and to the connection between the ultra-violet wave-radiation and the α-particles. It seems probable that the α-particles are products of radio-active processes occurring on the sun. This would explain, in a way not easy on any other hypothesis, the high speed and homogeneity of the corpuscular rays (§ 12). Again, the suggestion derives support from the existence of the other solar ionizing agent, the ultra-violet light radiation, which, as we have seen, is more penetrating than the corpuscular emission. In the past, before the evidence for the effective presence of *both* kinds of radiation was recognized, discussion concerned itself with the relative merits of the two—corpuscles and ultra-violet light—regarded as *alternative* ionizing agents. Two of the difficulties were as follows: in the case of the corpuscles, the accumulation of charge in the earth's atmosphere was mentioned as an argument against them—in the present review, the escape of accumulated charge is put forward as a main factor in the production of the magnetic storms associated with solar disturbance; in the case of the alternative agent, it seemed hard to understand how the ultra-violet light, supposed absorbed in the earth's atmosphere (since it does not reach the ground-level), could escape from the *sun's* atmosphere. Moreover, regarding the ultra-violet light as simply part of the ordinary radiation of the sun, treated as an incandescent "perfect" or "black-body" radiator, Swann had shown that the amount, even if the whole escaped from the sun, was quite inadequate to produce the observed ionization of the upper atmosphere. Both these difficulties are avoided if we suppose the ultra-violet light to consist of λ-rays, i. e. the extremely penetrating wave-radiation which in certain radioactive processes accompanies the emission of α-particles and β-particles. These λ-rays are immensely more penetrating than either β- or α-particles, so that as the latter prove able to escape from the sun's atmosphere, it is natural that the λ-rays should likewise do so; how far the speed of the particles is reduced in the solar atmosphere we cannot say, but the λ-rays which escape will maintain their superior penetrating power, and so ionize a layer in the terrestrial atmosphere lower than the auroral layer. The rays do not travel to a definite distance before absorption, as do the α-particles; their intensity diminishes exponentially with the mass of the gas traversed. As the density of the earth's atmosphere increases approximately exponentially with depth (reckoned from the outside), it is probable that the lower ionized layer in the atmosphere is ill-defined both above and below; the higher-lying auroral layer, on the contrary, though ill-defined above, has a sharply-marked lower limit.

The fact that both ionizing agents, though of such distinct kinds, are more intense during years of great than during years of little solar activity, argues for the existence of some physical connection between them, and is thus accordant with the hypothesis of their radioactive origin. The λ-radiation, however, seems to vary continuously and gradually, while the streams of corpuscles are discontinuous and intermittent. I am inclined to attribute this to the fact that the radiation, whether produced locally or, as seems more likely, all over the sun's surface, will spread out in all directions—what we receive at the earth coming from the whole of the emitting area. In the case of the corpuscles, probably they either cannot escape at all from the sun's general magnetic field, or can do so only in diffuse masses, except where the intense magnetic fields which Professor Hale has shown to exist over sunspots provide a "guide," analogous to a channel, along which they can stream outwards. The undoubted connection between disturbed areas on the sun and magnetic storms tends to support some such conclusion. Perhaps the study of the magnetic fields of sunspots will in time enable us to refer a given magnetic storm to a particular disturbed region on the sun, by indicating which region is associated with lines of magnetic force directed towards the earth; attempts by other methods to establish such a connection have never yet met with success. Hitherto there has been great uncertainty as to the time taken by the solar corpuscles to reach the earth; if they are α-particles, the time of passage can be assigned within fairly narrow limits, as from about two to three hours.

Nothing has so far been said about the β-particles emitted during the radio-active processes mentioned. It may be that these negative particles escape from the sun diffusely, or, if in streams with the α-particles, that they become dispersed, owing to their much greater deviability, before they reach the earth. Certainly they must escape from the sun in some way, as it is not to be supposed that the sun is steadily accumulating a negative charge; while there seems to be no evidence that two kinds of corpuscles reach the earth.

If the above suggestion is confirmed, that radio-active transformations on the sun are responsible for the emissions which affect the earth's atmosphere, such processes must play a much greater part in the economy of the sun than has generally been supposed; and they must be intimately connected with the cycle of variation of solar activity, for the ultra-violet wave radiation (here identified with λ-rays) is twice as intense at some sunspot maxima as at sunspot minima.

15. This completes the present account of the high-level atmospheric electrical phenomena which it has been my task to pass rapidly under review. The subject is by no means "cut and dried," and I have failed if any other impression of it has been given than that of a field of investigation which is unsurveyed on many sides, though across the unknown territory some well-explored regions can be glimpsed. So far as concerns the restricted aspect of it which has been considered here, the subject may seem to be a branch of meteorology, that, namely, which deals with the upper atmosphere not directly within the reach of our instruments. As yet it is too early to say how far a knowledge of these phenomena of the upper stratosphere is likely to assist in solving the important practical problem of weather prediction. These phenomena are, however, even more closely connected with solar physics—certainly, at any rate, in a more varied way—than is general meteorology, or than the latter is with the subject of this paper; and the study of them seems likely to contribute reciprocally to the advancement of solar physics in a way of which ordinary meteorology shows no promise. The secondary currents induced within the earth by those flowing in the upper atmosphere, again, extend the subject into a region quite distinct from atmospheric dynamics and thermodynamics, and provide one of the few means of research into the properties of the deep-lying interior of the earth.

While these studies may be expected to further other branches of science, those by the aid of which they must themselves be advanced are very numerous. Among them general physics—particularly electromagnetism, radio-activity, and spectroscopy—and mathematics, in addition to the sciences already named, come foremost. On the observational side the opportunities for valuable research are likewise numerous and varied, and, as in the case of astronomy, though to a less extent, many of them have been ably utilized by amateurs, as well as by those who have worked under the auspices of institutions maintained for the purpose of research. Probably few electrical engineers have leisure to devote themselves personally to the study of these somwhat remote ramifications of the science of electro-magnetism, but I hope that it may not be without interest to them to consider briefly such examples of how the principles underlying the more familiar applications of electricity are illustrated, in various ways and on a large scale, in Nature.

German Synthetic Rubber

THE full story of the efforts of German chemists and engineers, says *Chem. Trade J.*, 64 (1919), 26, to produce substitute materials during the four years' war scarcity will be an interesting one. Synthetic rubber, one of the most important of these substances, was more or less successfully made by Frantz Hoffmann, as early as 1912, but his experiments were partially abandoned on account of the lower cost of the natural rubber at the time. With the stimulation of the industry by the war demand, the process was improved and such difficulties as ready oxidation in the air and imperfect vulcanization were overcome. At a recent meeting of the Bunsen Society, in Berlin, it was stated that, in spite of the trouble in obtaining new materials, the production of methyl rubber had reached 165 tons per month, and a large factory at Leverkusen has a capacity of 2,000 tons yearly. The hard rubber, claimed to be a 20 per cent better electrical insulator than the natural rubber, was used for the accumulator boxes on submarines. The soft rubber, less easy to develop, is leather-like and inelastic at ordinary temperatures, but is given increased elasticity in manufactured articles by the addition of dimethylaniline and toluidine.

Experimental Wireless Telegraphy and Telephony—VIII*

Discussing Further the Action of Vacuum Tubes as Applied to Radio Communication

By Louis Gerard Pacent and Austin C. Lescarboura

WHILE acting in the capacity of a detector, the three-element vacuum tube is unlike any other type of detector; for, besides rectifying the current induced in the aerial circuit by the incoming oscillations, it also amplifies, and it is this latter characteristic that makes it the most sensitive detector in existence.

The amplifying action of the vacuum tube is readily explained if the reader will refer to Fig. 1, which accompanies this text. In this sketch it will be noted that an aerial or antenna, and ground are connected to the primary winding of a receiving transformer, and this winding, in turn, is in inductive relationship with a secondary winding L shunted by a variable condenser C_1 and then connected to a three-electrode vacuum tube with the necessary filament and plate batteries and other requisites, as already described in another instalment. As the incoming oscillations impinge on the aerial and travel up and down the

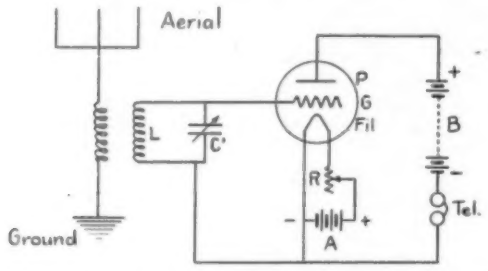


Fig. 1. Method of connecting three-electrode vacuum tube as a simple detector, without a grid condenser

antenna system on their journey to the ground, these oscillations are induced in the secondary coil L and they impress themselves between the *grid* and the filament. These are represented in graphical form in Fig. 2, at *A*.

Because of the uni-directional characteristics of the tube, the current in the plate circuit is *positive* only, but is of oscillating nature in direct resonance with the incoming oscillations, and the altitude or height of said oscillations is increased noticeably as shown at *B* in Fig. 2.

The ultimate result in the telephone receivers is shown in Fig. 2 at *C;* the high frequency oscillations are smoothed out by the inductance of the telephone receiver so that each train of high frequency current is a single impulse equivalent to the spark frequency, which is usually audible. The above explanation applies only when no grid condenser is used.

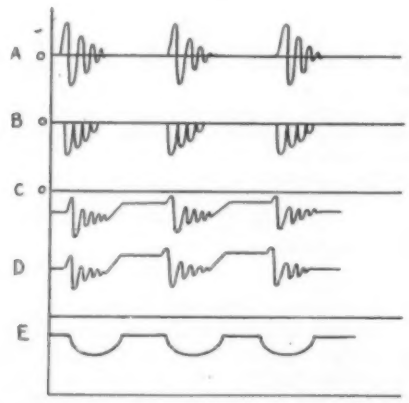


Fig. 4. Action of a vacuum tube when receiving with grid condenser

A. Incoming oscillations. *B.* Grid current. *C.* Grid potential. *D.* Plate current. *E.* Telephone current.

DETECTOR ACTION WITH CONDENSER IN GRID CIRCUIT.

If a grid condenser is used in accordance with Fig. 3, the action of the tube as a detector of incoming oscillations is quite different. The action now follows the exact form of the characteristic curve shown in instalment VII (SCIENTIFIC AMERICAN SUPPLEMENT No. 2285). When the voltage applied on the grid is of the same value as that of the filament and no grid oscillations are present, the grid current is zero; that is to say, no current or electrons are passing from the filament to the grid. Now if we suppose that a series of wave trains, as shown at *A* in Fig. 4, impinge on the antenna and the circuit LC, in Fig. 3, is tuned to them or is in resonance, then oscillations are set up in this circuit. If similar voltage oscillations are impressed on the grid through the grid condenser C_2—a condenser usually of 0.0002 microfarad capacity, each time the grid becomes positive, electrons will flow to it, but during the negative half of each oscillation no grid current will flow. This action is shown in Fig. 4 at *B*. The grid will continue to gain negative charges during each wave train, and then fall as shown in Fig. 4 at *C*.

As explained in a previous instalment, a negative charge on the grid always opposes the flow of elec-

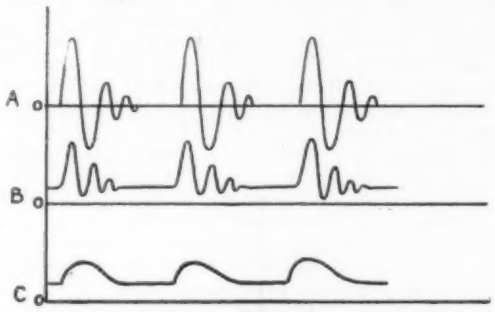


Fig. 2. Action of vacuum tube as a detector

A. Voltage oscillations impressed on the grid. *B.* Resulting plate current variation. *C.* Corresponding telephone current fluctuations.

trons, causing the plate current to decrease. This charged condenser leaks off either through the condenser or by the use of a high resistance placed across what is called the grid leak resistance, and the plate current resumes its normal value as shown at *D* in Fig. 4. The telephone diaphragm cannot vibrate at radio frequencies but it manages to smooth out the plate current variations into a form shown graphically in Fig. 4 at *E*, causing a note to be heard of a frequency corresponding to the transmitter's note.

AMPLIFYING ACTION OF VACUUM TUBE.

It has been pointed out that a vacuum tube rectifies because when an alternating voltage (incoming oscillation) is applied to the filament and grid, the current produced in the plate circuit is of oscillating nature but its oscillations are *positive* only. The plate oscillations have greater amplitude or vertical height, resulting in a louder response in the telephone. This is the reason why a vacuum tube is a more sensitive detector than the crystal type, which rectifies but does not amplify.

It is often desirable to amplify without rectifying an alternating current. This is done by keeping a voltage on the grid of such value that the symmetry of the oscillations in the plate circuit are not altered. Referring to Fig. 5, it will be noted that the input circuit is connected to the alternating voltage which is to be amplified, and that this is impressed between

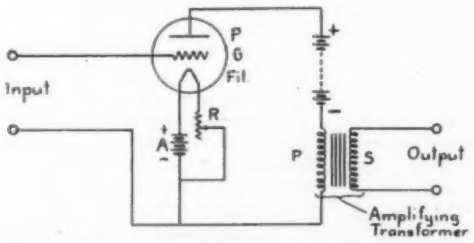


Fig. 5. Using vacuum tube as an amplifier—transformer coupled

the grid and the filament, so that the grid potential will alternate in accordance with the alternations of the applied electromotive force. These grid variations produce changes in the plate current of corresponding characteristics. For instance, if the mean potential of the grid and the amplitude of the applied electromotive force are such that the current in the plate circuit is always in that portion of its characteristic curve where it is a straight line, then the variations of the grid potential will be exactly duplicated in the variations of the plate current, both being in exact phase.

Taking into consideration Fig. 6, the portion *A* represents the grid variations due to the applied alternating electromotive force, and portion *B* represents the fluctuations of the plate current. For a given amplitude *A* the resultant amplitude of the component current in *B* will depend on the steepness of the characteristic curve of the plate. The applied alternating voltage on the grid supplies only the very small grid filament current, and the power drawn is very small, but the resultant power is quite considerable, thus resulting in a large volume of amplification. This large volume of amplification can be utilized by connecting it to the output circuit, or it can be diverted to the grid and filament of a second vacuum tube, and with proper design of the associated circuits a further amplification can be obtained. This can be carried through a number of progressive stages of amplification, but a limit is finally reached where howling begins. In regular practice amplification is limited to three stages for the type of circuit just described. This method is termed the audio-frequency amplifier, because the current is audible to the human ear when passed through a telephone receiver.

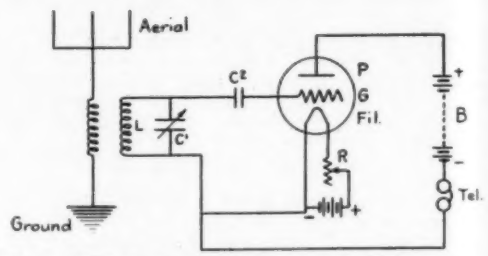


Fig. 3. Method of connecting three-electrode vacuum tube as a simple detector, with condenser in grid circuit

The Salvage of Leclanché Cells

IN a paper read before the Inst. of Railway Signal Engineers, W. J. Thorrowgood describes a method of renovating the porous pots of Leclanché cells. Mere soaking and washing proved to be useles, but it was noticed that the contents of such pots had an alkaline reaction. They were therefore allowed to stand in a solution of commercial hydrochloric acid (one part of acid to five parts of water), the depth of the acid being such that it comes nearly to the black rim at the top of the pot. The pots are allowed to stand for 24 hours in the acid. They are then washed and soaked in clean water for 48 hours, the water being changed after 24 hours' immersion. The cells are then ready for use. Service tests in railway working have shown that cells so treated stand up well. The method has been put to considerable use on the London and South Western Railway. It is also found that the interiors of spent dry cells may be used as porous pots. To render the sack interiors of spent cells suitable for use in place of porous pots the zinc case is removed, the jelly is washed away (in the case of Dania cells), leaving the interior to dry. A little pitch is heated and placed on the top of the sack and around the carbon rod, or the top of the sack and carbon rod when dry are varnished with an insulating varnish or paraffin wax to prevent the salts from

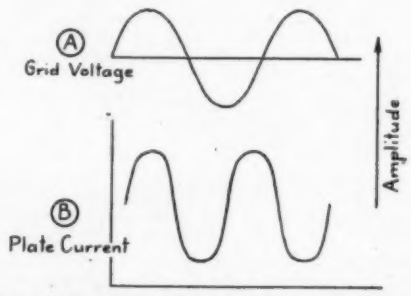


Fig. 6. Showing variation of plate current with grid voltage

creeping. The sack is then ready for use in an ordinary Leclanché cell. If a spent interior after being washed does not give satisfactory results in testing, it is submitted to the hydrochloric acid process, similarly to a spent porous pot, but for a shorter period. Up to March 31, 1919, 4165 interiors of spent dry cells were thus treated. It is found that one quart of hydrochloric acid is sufficient to treat 36 porous pots, and the average cost of material and labor, including war wage, is 2d. per pot. Spent interiors of dry cells cost 2.5d. to render useful. When porous pots are treated in bulk, say, about 40 at a time, the cost works out at 1.5d. each. It is estimated that the value of a treated porous pot or of a treated interior of a spent dry cell is approximately 50 to 60 per cent of that of a new porous pot.—*Science Abstracts.*

*This article is one of a series appearing in the SCIENTIFIC AMERICAN SUPPLEMENT for the past few months. The first instalment appeared in the issue dated July 5, 1919, No. 2270. Back numbers may be obtained as long as the supply lasts. (Copyrighted, Scientific American Publishing Company.)

Heating of Underground Cables*

Tests to Determine Safe Operating Intermittent Loads

By A. L. Freret, Asst. Electrical Engineer, Tenessee Coal, Iron and Railroad Co., Birmingham, Ala.

ELECTRICAL conductors, whether bare or insulated, are either carried on insulators when they are surrounded by air, or they are made into cables carried in conduits, which latter generally are surrounded by a solid substance such as earth or cement.

When a bare or insulated cable is carried in air the convection of heat due to air currents is so rapid that the carrying capacity of the conductor is not limited by temperature but is restricted only by the losses which the power producer can afford to allow.

When a cable is carried in a conduit buried in solid material convection of heat is prohibited, and the heat created by the current in the cable must therefore be dissipated by conduction through the insulation and through the conduit into the sold surrounding substance.

The amount of heat thus dissipated through conduction is roughly proportional to the difference in temperature of the conductor and of the surrounding solid substance and is also proportional to the area of the radiating conductor.

When current is admitted to the cable the temperature of the conductor commences to rise, and it is evident that with constant current stable condition or constant temperature of the conductor cannot be reached until the conductor has risen in temperature just to the point when exactly the same amount of heat is conducted from it to the surrounding substances as is created within by the electric current.

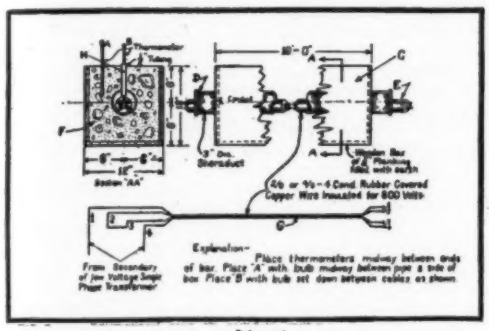


Fig. 1

This process of conduction of heat from the cable is so slow compared to the process of convection from a conductor suspended in air that the limiting carrying capacity of the underground cable is the temperature dangerous to the insulation and this temperature is reached long before the power losses represented by the heating reach values which need be seriously considered.

If we were to plot a curve showing temperature as

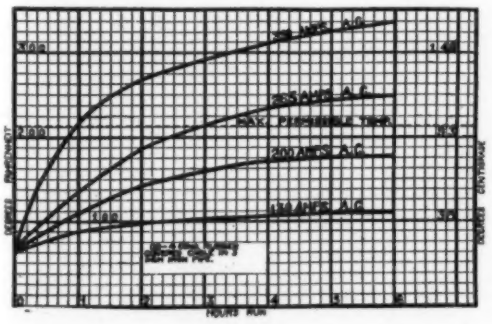


Fig. 2

ordinates against time as abscissæ, this curve, if commenced before the conductor carried any current, would evidently begin with a horizontal line representing the common temperature of the cable and the surrounding material. When current is switched on the curve must bend upwards with rising temperature of the cable and then gradually bend toward the horizontal again as we approach the temperature at which the same amount of heat is conducted away, per unit of time, as is created within the cable.

For each value of current carried by the conductor we would thus obtain a different maximum temperature rise.

Various text-books and catalogs published by cable manufacturers show temperature rise for various sizes of cables carrying current of different values. The literature, however, lacks information as to rise in temperature with intermittent current values. It is self-evident that we can permit much larger currents for short periods if we give the cable time to cool off somewhat between the recurrent loads.

In order to arrive at some conclusion as to safe operating intermittent loads on underground cables experiments were made which will now be stated and the results of which are compiled on the tables and figures shown herewith. We tried to approach, as near as possible, the conditions that would be met in the field.

In Fig. "C" is a pine box 10′ 0″ long, 12″ × 12″ outside measurement, built of ⅞″ pine boards. A piece of 3″ Sherarduct "D" was placed in the center of box "C" and surrounded with ground firmly packed around it. "E" is a piece of four conductor rubber covered cable placed in conduit, and "G" shows the method of connecting the ends of cable—the source of power being applied at "No. 1 and No. 4." Section "AA" shows the two thermometers "A & B," one "A" being placed in the ground "F" and the other "B" being placed in the center of cable "E" between the four conductors of this cable, a fiber tube "H" having been provided to prevent the ground from crushing the thermometer or entering the sherarduct "D."

TABLE 1
00 4/Cond. Rubber Covered Cable

Hours	130 amps.		200 amps.		265 amps.		350 amps.	
	Cable	Earth	Cable	Earth	Cable	Earth	Cable	Earth
1	88°	68°	112°	71°	136°	76°	222°	82°
2	96°	68°	146°	75°	192°	81°	269°	90°
3	100°	69°	156°	78°	215°	89°	292°	100°
4	106°	70°	174°	82°	237°	96°	312°	108°
5	108°	72°	174°	83°	237°*	102°	328°	117°
6	110°	73°	180°	84°	248°	107°	339°	122°

Room temperature for 130 amperes =66°. For 200 amperes =70°.
Room temperature for 265 amperes =76°. For 350 amperes =80°
* Tar running out.

TABLE 2
0000 4/Cond. Rubber Covered Cable

Hours	150 amps.		200 amps.		300 amps.		400 amps.	
	Cable	Earth	Cable	Earth	Cable	Earth	Cable	Earth
1	84°	66°	98°	70°	148°	72°	226°	79°
2	92°	68°	118°	72°	180°	78°	250°	88°
3	96°	70°	128°	76°	202°*	82°	290°	99°
4	100°	70°	134°	76°	212°	87°	310°	109°
5	102°	72°	140°	84°	220°	96°	330°	110°
6	104°	73°	146°	86°	240°	100°	332°	118°

Room temperature for 150 amperes =56°
Room temperature for 200 amperes =70°
Room temperature for 300 amperes =79°
Room temperature for 400 amperes =74°
* Tar running out; smoking.

TABLE 3

Minutes	## 4/Cond. cable—200 amps.		0000 4/Cond. cable—300 amps.	
	Cable	Earth	Cable	Earth
3	81°	77°	77°	74°
6	83°	77°	84°	74°
9	85°	78°	88°	74°
15	87°	78°	88°	74°
21	89°	78°	92°	74°
30	91°	78°	94°	74°
39	94°	78°	100°	74°
45	94°	78°	100°	74°
54	98°	78°	106°	74°
60	98°	78°	106°	74°
66	100°	78°	110°	74°
75	101°	78°	110°	74°
81	102°	78°	113°	74°
90	103°	78°	114°	74°
96	105°	78°	116°	74°
105	105°	78°	116°	74°
111	106°	78°	119°	74°
120	107°	78°	119°	74°

All temperatures on these tables are Fahrenheit.

The power for this test was furnished by a low voltage 25-cycle transformer and the usual meters and resistances used to record and maintain the current at the desired values.

Table No. 1 is a record of the first series of tests. A 2/0 four conductor rubber insulated and braided cable was tested at four different current values—the lowest 130 amperes and the highest 350 amperes—each run continued for about six hours, the current being kept as constant as possible and the whole equipment was allowed to cool off between each test. These tests are also shown in the form of curves in Fig. 2.

If we allow a maximum permissible temperature in the cable of 100° C. (212° F.) we notice that this cable should only be allowed to carry 200 amperes continuously. Already 265 amperes would carry the temperature beyond the danger point.

In the same manner a 4/0 four conductor rubber covered cable was tested and readings recorded in Table 2; corresponding temperature curves are shown on Fig. 3. It will be noticed that already 300 amperes carries the temperature of the cable to the danger point.

After the above series of tests was finished a new test was made using the same cables with 200 amperes on the 2/0 cable and 300 amperes on the 4/0 cables—these being the currents that we wished to use on these cables in actual work. These currents were applied for one minute and the temperature rise recorded. Then current was shut off for two minutes and this process was kept up for two hours. The results are shown by curves on Fig. 4.

In the case of the 4/0 cable carrying 300 amperes we now reach a temperature of about 41° C. (107° F.) instead of 82° C. (180° F.) with continuous load, or a difference of 41° C. (73° F.).

In the case of the 4/0 cable carrying 300 amperes, we now reach a temperature of 49° C. (120° F.) against 104° C. (220° F.) with continuous load, or a difference of 55° C. (100° F.).

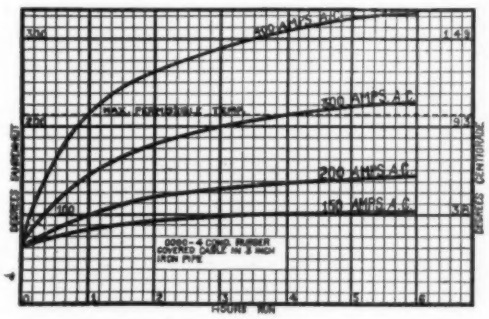


Fig. 3

We might therefore conclude that with an intermittent load, one minute on and two minutes off, an underground cable need only have 56 per cent area of the conductor for carrying the same load continuously.

The foregoing shows that the current being intermittent, the heating of the cable really depends upon the mean effective current, which is the square root of the mean squares of the current. In the case where

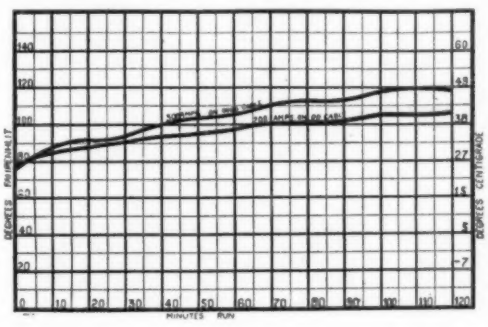


Fig. 4

the current is on and off the same length of time, that is, one minute, this would correspond to the √2 and for current alternations amounting to one minute on and two off, this same value is very nearly correct, so that the simplest way to arrive at the safe value of current for underground cables in intermittent service would be to use the manufacturer's rating multiplied by the √2.

*From *Jour. Engineers' Club of Philadelphia.*

Methods for Rendering Cement Waterproof

CEMENT can be waterproofed by the addition of 10 per cent petroleum oil immediately after mixing, but the time taken for the cement to set is almost doubled. An effective method for treating reservoir walls already cemented is to coat the wall surfaces with a 20 per cent solution of paraffin-wax in gasoline. Another method is to damp them with soapy water, then after about 24 hours to pass a solution of sulphate of alumina over the walls. This operation should be repeated several times.—From *La Nature.*

Coke for Domestic Heating*

Why and How This Fuel Should Be Used in the House Heating Furnace

By Henry Kreisinger and A. C. Fieldner

COKE should be used for heating houses because it is a clean and convenient fuel. It eliminates smoke, reduces the necessity of cleaning the furnace and flues, requires less attention than coal, and gives a more uniform temperature in the house. By burning coke for domestic heating, more soft coal will be used in by-product plants, which save many valuable by-products that are wasted when the coal is used directly in the raw state. The by-products of popular interest obtained in the coking process are gas, light oils, ammonia, and tar.

The only way of eliminating smoke in large cities is to use smokeless fuel—a fuel that will burn without producing smoke in any equipment now in use. In the past the only smokeless fuel available for house heating was anthracite. However, anthracite is mined in only one district in the United States and, therefore, its use is limited to the area lying within reasonable freight distance of the anthracite mines. Much the larger part of the country has to depend on soft coal for domestic heating. Inasmuch as coking coal can be found in many places in the United States it is possible and desirable that part of the bituminous coal should be converted into coke to supply a smokeless fuel for household use. It is also possible to burn coke in small power plants that cannot use mechanical stokers and are situated in the heart of a city where fuel should be burned without smoke.

COST OF SMOKE TO THE COMMUNITY.

The cost of smoke to the community has been investigated in detail in several large cities. The committee on smoke prevention of the Cleveland Chamber of Commerce in 1909 fixed the annual loss due to smoke in the city of Cleveland at $6,000,000, or about $12 for every man, woman and child each year.

Similar investigations made by the Mellon Institute in Pittsburgh showed a total annual cost of $10,000,000, or about $20 per capita. This estimate does not include such items as depreciation in value of property, compulsory absence of certain industries, injury to health, or impaired mental efficiency.

In view of this large cost of smoke to the city, would it not pay to exert some effort to eliminate smoke by providing smokeless fuel and have a much pleasanter place in which to live and enjoy the good health that goes with a pure, wholesome atmosphere?

When burning coke a furnace requires much less attention than when burning soft coal. The time usually given to poking fires, cleaning the furnace flues and the house, can be spent much more profitably in some other way. Surely the most disagreeable work a householder is called upon to do is to clean the soot out of his furnace and flues. Moreover, the cleaning is not limited to the furnace and flues alone, but extends to the entire house. With hot-air heating, particularly, some of the soot may be carried into the house, necessitating more frequent house cleaning, curtain washing, and papering. The cleanliness of coke will appeal especially to the housewife.

Using coke in house-heating apparatus will provide the coke producer with a market for the small-size coke, thus allowing him to supply coke of uniformly large size which is needed for metallurgical purposes. Thus, the use of coke in heating houses will improve the fuel efficiency of the metallurgical industries.

VALUE OF GAS AS A BY-PRODUCT.

When one ton of soft coal is coked in a by-product plant about 5,000 cubic feet of gas is made available for outside use. This gas is particularly well adapted for cooking, ironing, and, where electricity is not available, for lighting. It is also a convenient fuel to be used in small gas stoves or, even open grates late in the spring and early in the fall, when the weather is too warm to use the regular furnace and too cold for no fire. A small gas stove can be lighted readily and the room made comfortable for dressing in the morning and for retiring at night. Gas is particularly well adapted for water heaters, and for bath-room heating. All these features add to the pleasures of life.

Those housewives who once use gas for cooking appreciate its conveniences and cleanliness; they never want to go back to the dirty coal or wood stove. There is no coal or wood to be carried into the house, no ashes and soot to remove from the stoves and carry out of the house. The ash and soot are always a horror to the housewife, because in cleaning the stove the ash and soot are scattered through the house and mean so much additional work to keep the house clean.

When gas is used for cooking the fire is always ready and the heat can be controlled with a nicety that cannot be obtained with any other fuel. Instead of building up the fire and waiting for the stove to get hot before cooking can start, the gas is instantly available for work, thus the housewife is saved a great deal of time. We must appreciate the fact that the housewives, too, want shorter hours.

The readiness of the gas fire for cooking is especially appreciated on hot summer days. With the ordinary coal or wood stoves practically the whole stove must be heated before anything can be cooked on it, whereas with the gas fire only a small flame is burning, and that where the heat is needed, the rest of the stove remaining cool. When any particular cooking process is done the fire can be turned off and no fuel is wasted. Such is not the case with a coal fire. The fire must be left burning until it burns out, unnecessarily heating the kitchen and making it uncomfortable. Oftentimes the fire must be kept going between the cooking of two meals. Thus the efficiency of the gas fire is very much higher than the coal fire. Although the cost of heat in the form of gas may be ten times as much as the cost of heat in the coal, it may be cheaper in the end to burn the gas, because it is used so much more efficiently.

Aside from the efficiency of the gas, the comfort of the housewife demands consideration. She also wants to have her work made lighter and more pleasant. The man equips his shops and offices with the latest, most up-to-date, labor-saving machinery, frequently without consideration of the cost. Why should not the housewife be allowed to share the benefits of modern improvements and inventions? Instead of allowing her to perspire around the coal stove that her grandmother used, why not provide her with a modern gas fire for cooking and for heating water for cleaning and washing, thus making her work lighter and her life more pleasant?

Gas cannot be made to sell at a reasonable price for household use unless the by-product, coke, is fully utilized. Only by selling a large quantity of coke for house-heating purposes can the by-product plant operator afford to deliver the gas to the householder at a reasonable price.

As a part of a general investigation of more efficient methods of utilizing the fuel resources of the country and the elimination of smoke in cities, the Bureau of Mines is conducting experiments on the burning of coke and other fuels in house-heating furnaces, with the object of demonstrating that soft coal can be so prepared by conversion into smokeless fuels, coke and gas, that all the materials in the coal are used to best advantage.

This paper discusses the advantages of coke as a fuel, and points out how coke should be burned in heating houses. The information applies both to gas coke and to by-product coke.—EDITOR.

VALUE OF LIGHT OIL, AMMONIA AND TAR.

The process of coking 1 ton of soft coal yields about 3 gallons of light oils suitable for motor fuel. At present prices the heat in the light oil has about 20 times the commercial value of the same amount of heat in the form of coal. When our mineral supply of oil is exhausted soft coal will be our chief source of motor fuel. The light oil recovered from coking soft coal now supplies part of the ever increasing demand for motor fuel. It may be added here that during part of the war, Germany was practically cut off from every supply of mineral oil. She depended for her motor fuel entirely on her coal. As a result of that conditon Germany has sent most of her coal through by-product coking plants. What has been done in Germany may in the future have to be done in the United States.

When soft coal is burned in house-heating furnaces most of the light oil escapes unburned and is wasted. By converting the coal into coke and using coke as a house-heating fuel the light oil obtained as a by-product helps to replenish our decreasing supply of motor fuel. A part of the light oil consists of toluol, which in time of war can be separated from the remainder of the light oil for the manufacture of TNT. Modern warfare requires enormous quantities of this substance for making high-explosive shells. There should be an adequate supply of toluol for national protection. During the first part of the war the Allies came near defeat for the lack of this material. Utilization of the light oil tends to reduce the cost of converting coal into smokeless fuel.

The ammonia that is recovered in the process of converting soft coal into coke is used for various purposes. Its chief value lies in its nitrogen content, 17 pounds of ammonia containing 14 pounds of nitrogen. One of the most important uses of ammonia is in making artificial fertilizers. More fertilizer means more productive farms, which are especially desirable in the thickly populated industrial States where a large quantity of food is needed. If the food is produced where it is used, transportation charges are eliminated, and thus the cost of food is materially reduced. Hence the coking of coal in by-product plants produces large quantities of ammonia for fertilizer, and thus helps to reduce the cost of living. Ammonia is also used in artificial ice making, cleaning, and in the manufacture of nitric acid. Nitric acid is used for making explosives for mining coal.

When soft coal is burned in its raw form in any kind of furnace, the ammonia, which contains the nitrogen of the coal, escapes into the air and is wasted. It has been frequently proposed to build large hydraulic power stations to generate cheap electricity and use the electricity to obtain nitrogen from the air. Why should soft coal be burned in a raw state, discharging all its contained nitrogen into the atmosphere, and then expensive hydraulic plants be built to get back from the atmosphere part of the nitrogen wasted in burning the raw coal? Why not get the nitrogen directly from the coal by coking in a by-product recovery plant? Burning coke to heat houses encourages the development of this economical use of coal and the production of cheap ammonia.

Coal tar is used in the manufacture of a large number of drugs, dyes, explosives, paints, wood preservatives, road dressing, roofing and building papers, and a great veriety of other useful articles. The number of new articles made from coal tar are increasing daily. Coal tar is also used successfully in place of fuel oil for metallurgical purposes. In fact, it seems that the usefulness of coal tar has been barely touched.

When soft coal burns in house-heating furnaces most of the tar escapes unburned and is not only wasted but pollutes the atmosphere with very sticky dirt. Coking the soft coal in by-product plants provides smokeless fuel for heating houses and recovery of the useful tar.

INCREASED VALUE OF PRODUCTS OF THE COKING PROCESS.

When 1 ton of soft coal having a market price of $7 per ton is coked by a by-product plant the chief products obtained have the value shown in the following table:

TABLE 1.—*Value of by-products obtained by coking one ton of coal.*

Cost of 1 ton of coal	$7.00
1 ton of coal produces—	
0.65 ton of coke, worth	6.00
5,000 cubic feet of gas, worth	5.00
3 gallons motor oil, worth	.75
9 gallons tar, worth	.25
25 pounds ammonium sulphate, worth	1.25
Total value of products	$13.25
Less cost of 1 ton of coal	7.00
Increased value	$6.25

The table shows that the products of the coking process have a market value about 90 per cent greater than the original coal. This increased value is due mainly to the human labor expended in the coking process, because it takes a great variety of labor to plan, build, and operate a by-product plant. High technical skill—that of engineers, chemists, and draftsmen—is required in making the plans for a by-product plant, a large number of skilled and unskilled workmen are needed to erect the plant, and a large number of skilled and unskilled workmen are necessary to supply the material needed in its erection. Skilled and unskilled labor has to distribute to consumers the by-product gas; a large number of technical men, and skilled and unskilled labor are needed to operate the plant; and many chemists are kept busy getting drugs, dyes, paints, and other products out of tars. Therefore, by using coke, employment is given to a large number of men. The increased value of the products represents the labor that has been expended in making these products available.

The use of bituminous coal will develop in much the same way as waste in meat packing has been eliminated. Thirty years or more ago a large amount of material from the slaughtered cattle was thrown away and thus not only was largely wasted but became a nuisance by polluting streams and the atmosphere. At present everything from the slaughtered cattle is utilized; the packing industries employ thousands of skilled and unskilled workmen, and the meat-packing centers are no more a horror to the inhabitants of the surrounding country.

In the past soft coal has been burned in the raw state in dwelling houses and in many plants not equipped for its efficient utilization. A large part of the valuable substances in the coal escaped as black smoke, was wasted and polluted the atmosphere. In spite of the efforts that were exerted to improve the furnace in order to obtain smokeless combustion the smoke largely persisted. Now people are realizing that

*Technical Paper, 242, Bureau of Mines.

the smoke from a chimney is a warning to man that he is not using the coal he should. Times are changing; a large part of the soft coal output of the country is sent through the by-product plant, and substances that were previously wasted as smoke are now turned into valuable products, and at the same time a smokeless fuel (coke) is made available for burning in almost any kind of heating apparatus.

HOW TO BURN COKE IN HOUSE-HEATING EQUIPMENT.

For starting a fire in an ordinary furnace or boiler in a 6 to 10-room residence about 10 to 15 pounds of kindling wood is needed. When the wood is well ignited it should be covered with a layer of coke about 6 inches thick. It will usually take one hour to get this first layer of coke burning nicely. All the available draft should be used to start a fire; the stronger the draft the sooner the fire will start. After the first layer of coke is well ignited the furnace should be filled to a depth of 14 to 18 inches, and the draft checked to allow the coke to burn slowly.

DRAFT.

To get good results from a coke fire the draft must be kept under control. The amount of draft required depends on the weather conditions and the size of the coke. Generally speaking, it takes much less draft to burn coke than it does to burn anthracite or bituminous coal. If too strong a draft is used after the fire is started, the coke will burn too fast, making the house too hot and requiring frequent firing. Proper regulation of the draft is therefore highly essential.

The draft is regulated mainly with three dampers, designated in figure 1 by the letters A, B and C. Damper A is in the smoke pipe connecting the furnace with the chimney. This damper usually consists of an opening covered with a hinged lid. When this lid is closed the full draft of the chimney is effective in the furnace. When the lid is lifted the chimney draws air from the cellar instead of drawing the gases out of the furnace, and the draft in the furnace is reduced almost to nothing. In some furnaces the damper in the smoke pipe is of the form shown by D. When the damper D is open the full draft of the chimney draft becomes available in the furnace; when it is closed the draft in the furnace is reduced almost to zero. Some furnaces and boilers are equipped with both damper A and damper B. Either one can be used to regulate the chimney draft.

The damper B on the ash-pit door regulates the flow of air through the fuel bed, and the amount of air flowing through the fuel bed determines the rate of combustion, which is the amount of coal that the furnace can burn in an hour. Therefore, to control the rate of combustion and thereby regulate the amount of heat the furnace delivers to the house, the furnace attendant adjusts the damper in the ash-pit door and the check damper in the smoke pipe. In many furnaces the ash-pit door fits so loosely that enough air flows into the ash pit even when the damper in the ash-pit door is closed. In fact this leakage may be so great that keeping a fire over night may be difficult. If this is the case the leakage of air into the ash pit should be stopped by refitting doors or dampers or closing openings and cracks with cement or "smooth-on."

The damper C in the firing door supplies air over the fire, this air being needed to burn the combustible gases rising from the fuel bed, and regulation of the damper controls the completeness of combustion. In many furnaces and boilers the damper and the firing door fit so losely that enough air enters into the furnace for complete combustion even when the damper is closed. An opening of about one-eighth inch in the average damper will be enough.

If the size of the furnace will permit the fuel bed should be carried about 18 inches thick. A thick fuel bed helps to check the draft and gives slow uniform combustion and uniform temperature in the house. With a thick fuel bed the fire will last a long time without requiring attention. If a thin fuel bed is carried the coke burns too fast, giving a hot uneven fire that burns out quickly and requires frequent firing. A thin fire also tends to produce more clinkers.

SHAKING THE GRATE.

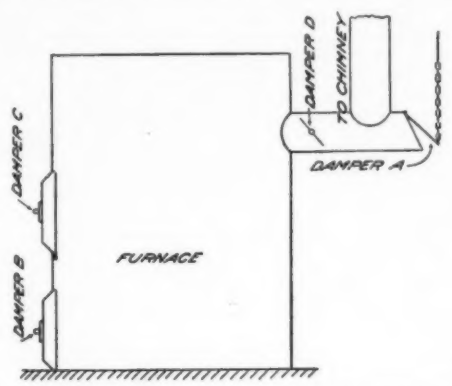
A coke fire requires less shaking of the grate than a coal fire. In ordinary weather one shaking a day, preferably in the morning, is all that will be necessary. In very cold weather the grate may have to be shaken before each firing. Usually better results are obtained when the grate is not shaken too much, and it should never be shaken so much that pieces of hot coke fall into the ashpit. Therefore in shaking the grate the ashpit should be watched and the shaking should stop as soon as the first sparks appear in the ashpit. Some people who have burned coke for many years say that they get better results if they leave a layer of ashes about 1 to 2 inches thick on the grate all the time. The ashes help to check the draft and keep the hot coke from coming in contact with the grate. Between firings the fuel bed should be stirred as little as possible.

If clinkers form on the grate they should be pulled out just before firing. Usually the best time to remove clinkers is in the morning, when the fire is started for a day's run. It often happens that this one cleaning is sufficient, and sometimes the fire may go two or three days without removing the clinkers, particularly if the weather is mild. The less the fire is disturbed the better satisfaction is obtained with coke.

The ash should not be allowed to accumulate in the ashpit until it reaches the grate, for then the grate will be injured. Therefore it may be well to remove the ash from the ashpit every day.

SIZE OF COKE.

The best size of coke for house-heating furnaces and stoves is between one-half inch and 2 inches. If a larger size is used the coke burns too fast and requires more frequent firing. For open grates the size of the coke may be somewhat larger, ranging from one-half inch to 4 inches. It should be remembered that coke is much lighter than anthracite and bituminous coal. Therefore a greater bulk of coke should be fired at a time than when burning coal. Pieces of coke are more angular and have rougher surfaces than pieces of bituminous or hard coal, hence the latter can be packed more tightly in the fuel bed than those of coke. Consequently the spaces between the pieces of coke are much larger than those between the pieces of coal and allow much freer passage of air. This is why coke requires less draft than either soft or hard coal. To make the coak pack more tightly on the fuel bed and reduce the spaces between the individual pieces it may be advantageous after firing to tap the coke down with a poker. This patting will also permit of firing more coke at a time than if the coke is thrown in loosely with a shovel and the fire will go longer without attention.



Position of dampers in a house-heating furnace

Damper *A* regulates the draft in the furnace and should be used with dampers *B* and *C*. Damper *B* regulates the supply of air through the grate and the rate at which the coal burns. Damper *C* regulates the supply of air over the fire and the completeness of combustion. Damper *D* controls the draft and should be used with damper *A*.

TABLE 2.—*Results of tests with by-product coke.*

Proportion of boiler capacity developed.	Average period between firing.	Duration of tests.	Overall efficiency.
Per cent.	*Hours.*	*Hours.*	*Per cent.*
52	4	96	73
88	4	120	72
122	3	120	63

Table 2

TABLE 3.—*Results of tests of various fuels in house-heating boilers.*

(Tests made at the engineering experiment station of the University of Illinois.)

Fuel.	Efficiency of boiler and furnace.	Fuel fired at each firing.	Average interval between firing.	Rated capacity developed.
	Per cent.	*Pounds.*	*Hours.*	*Per cent.*
By-product coke	61.63	75	3.71	64.46
Gas-house coke	56.22	75	3.21	65.48
Anthracite	51.93	75	2.47	66.00
Illinois coal, Williamson County	48.09	75	2.92	64.04
Pocahontas coal	46.51	75	3.30	63.88

Table 3

For banking the fire over night, the fines from the coke pile should be used. The fines make a denser fuel, reduce the draft through the fuel bed, and thus help in keeping the fire over night. The fuel bed may be made still denser by lightly tapping the coke on top with a poker or shovel. The ash pit door should be closed as tightly as possible and the draft in the furnace reduced by opening the check damper in the smoke pipe. If the ash pit door does not fit tightly, in order to keep the fire over night it may be necessary to open the damper in the firing door.

STARTING THE FIRE IN THE MORNING.

In the morning, if a good bed of hot coke about 6 inches thick is on the grate, the grate may be shaken, clinkers removed, the fire leveled, and a heavy charge of coke placed in the furnace. Opening the damper in the ash pit and closing the check damper in the smoke pipe will help to start the fire quickly. After about half an hour, when the freshly fired coke has been well ignited, the damper in the ash pit door can be nearly closed and the check damper partly opened. The magnitude of the opening of the check damper depends on the severity of the weather and on the available chimney draft, and must be determined to suit each individual furnace.

If the fire is almost burned out in the morning, it is well not to shake the grate or remove the clinker, but level the fire with a poker, slightly stirring it so as to shake some of the ashes down in the ashpit, and then fire about a 6-inch layer of coke, open the damper in the ashpit, close the check damper in the smoke pipe, and also close the damper in the fire door. In about half an hour the thin layer of freshly fired coke is well ignited and a heavy firing can be put in to last the greater part of the day. If there is an excessive amount of ash or clinker on the grate the grate can be shaken and the clinker removed through the firing door before putting in the heavy firing.

FIVE RULES TO BE OBSERVED.

The directions for burning coke can be condensed into five rules, as follows:

1. Carry a deep bed of fuel; a bed about 18 inches thick gives best results.
2. Use very little draft after the fire is started and keep it always under control.
3. Do not stir the fuel bed; clean the fire in the morning, if possible.
4. Use sized coke; ½ to 2 inches for furnaces, boilers, and stoves; ½ to 4 inches for open grates.
5. Do not allow ashes to accumulate in ash pit.

ADVANTAGES OF COKE AS HOUSE-HEATING FUEL.

Coke is a smokeless and clean fuel and offers the best means of making our large cities smokeless. It is known that in large cities where soft coal is burned for domestic heating about 60 per cent of all the smoke in the atmosphere is made in the residential section in house-heating furnaces. Substituting coke for soft coal will eliminate this 60 per cent of smoke. The smoke made in house-heating furnaces is much more objectionable than the smoke made in industrial plants because it is made in the residence section where it does the most harm.

Coke does not make any soot, consequently the cleaning of boilers, smoke pipes and flues is eliminated. Those who spend their Saturday afternoons or Sundays cleaning furnaces and flues will appreciate this advantage. Soot is a poor conductor of heat; when it is deposited on the heating surfaces of the boiler or furnace much less heat is utilized in heating the house, and a large part of the heat passes up the chimney. All formation of soot means a direct loss, because it represents that much unburned coal.

Soft coal can never be burned in house-heating furnaces with such completeness of combustion as coke. When soft coal is used most of the volatile matter distilled from the coal escapes from the furnace unburned in the form of soot, tar, and combustible gases. Part of the soot and tar is deposited on the heating surfaces of the stove or furnace and in the flues and part escapes through the chimney as visible smoke. The unburned gases go up the chimney with the visible smoke. The tar and soot do not burn in the furnace because the furnace is usually too small and the temperature too low for maintaining their combustion. The residue left after the tar and soot have been driven from the coal is in the form of coke. It burns slowly and almost completely in the small furnace and the heat which gets into the house is mostly the heat that has been generated by burning this residue.

Therefore, when soft coal is burned in the ordinary house-heating furnace the coal is first reduced to coke by driving off the volatile matter, most of which escapes unburned; then the coke burns in the furnace and heats the house. Driving off the volatile matter unburned not only causes a direct loss of heat but causes a great deal of dirt in the furnace, flues, boiler room, and also in the outside atmosphere. Since the volatile matter in soft coal is of negative value so far as heating the house is concerned, it is better to use a fuel that does not contain volatile matter. Such a fuel is coke. Most of the coke on the market for domestic heating is made in special furnaces by driving off the volatile matter. From this volatile matter are obtained gas, tar, and other by-products that have a high market value. Therefore, by converting the coal into coke in these special coking plants the volatile matter, instead of being a nuisance, is turned into a source of national wealth.

Results of investigations of the value of different fuels, including coke, anthracite, and soft coals of various kinds, as fuel for house-heating furnaces will be published in a separate bulletin by the Bureau of

Mines. The results obtained thus far show that coke can be burned in house-heating furnaces much more efficiently than soft coal.

The results obtained with coke under a steam boiler of a size to supply 800 square feet of radiation are summarized in Table 2.

The table shows that more than 70 per cent of the heat in the coke was usefully employed in heating the house.

Some time ago the engineering experiment station of the University of Illinois made comparative tests of by-product coke, gas-house coke, Pocahontas coal, and Illinois coal. The results of these tests are printed in Bulletin No. 19 of the University of Illinois. Table 3 gives the summary of results of tests obtained with a boiler capable of supplying 800 square feet of radiation:

Table 3 shows that with coke about 61½ per cent of the heat in the fuel was utilized in heating the house, whereas, with Illinois coal, only 48 per cent of the heat was utilized. Hence if the coal and the coke contained the same amount of heat, about 7¾ tons of coke will deliver as much heat into the house as 10 tons of the soft coal. In addition to this higher efficiency from coke, the furnace and boiler room are kept clean with less work and there is no smoke to pollute the atmosphere.

The Effect of Electric Light on the Eye*

By Herr Reichenbach

MODERN developments regard improvements in electric light as a case of increased efficiency, leading in the end to a lowering of prices. The effects from the point of view of hygiene are not considered; though any improvement of this sort would be welcome, it is not by any means a deciding factor. Still, hygienically considered, much progress in the sphere of lighting has been made, mainly owing to the cheapness at which electric light can be supplied. In 1901 Prausnitz said that it was impossible to provide 10 lux for reading and writing; moreover, he considered that even if it were possible, it would be unnecessary. H. Cohn has now shown by his important work that this figure should be regarded as a minimum. Cohn thinks that 50 meter-candles are desirable, based on the Wallrat candle-power, which corresponds to 57 lux, determined by the Hefner candle-power. There are certain objections to be made to Cohn's methods and assumptions; still the author thinks that 60 lux ought to be regarded as the desirable mean value for the illumination. Having regard to the eye's mean capacity for clear vision, 25 lux should be taken as a minimum, and there are no difficulties nowadays in providing light on this scale. It can even be obtained by indirect illumination, which is specially good for the eye. The heating caused by the usual electric lights is so small that it may almost be neglected, even in the case of workshops. Still, white-hot bodies always emit a not inconsiderable amount of infra-red radiation, toward which, according to Vogt, the refractive media of the eye are comparatively transparent, more so than has been commonly supposed to be the case with heat rays. But it is doubtful whether any injury results, and this cannot be determined without further experience.

The quantitative changes of the newer types of light depend mostly on the higher temperature of the illuminant; this increases the brightness of the surface, the color over the visible portion of the spectrum changes and more ultra-violet rays are emitted. It is partly of a physical and partly of a physiological nature to determine what ill effects are to be ascribed to an increased brightness in the surface of the illuminant; in fact, to find out what are the effects of "glare" is a somewhat complex problem. The length of time over which the eye is exposed is a part of the question; obviously this must not continue till permanent injury results. Further, there is the breadth of pupil in the individual, the conditions of adaptability, irradiation (the filaments of a glow lamp always appear broader than they actually are), and the distance of the light; also the amount of the light from unit-surface that actually reaches the eye, and the effect produced by this light. Of the present illuminants, none correspond even distantly to Stockhausen's maximum of 0.75 Hefner candles per square centimeter, or even to the Hertel-Henker standard of 0.2 or 0.3. Therefore, we can only attempt to make this great surface-illumination as little harmful as possible. The author suggests that lamps should be surrounded with diffusing media; they should not be centrally before the eyes; it would even be well if the gare did not fall on the eye from the side, as this is known to be physiologically harmful. Shades, covered with green, are useful. The indirect system of lighting has many advantages, but the absence of shadows is in some cases a positive disadvantage, as in the workshops of a scientific instrument maker. A number of small lamps on the ceiling is a very advantageous system, and would be more efficient than the indirect method were it not for the fact that the small lamps in themselves are less evident than one large illuminant. But in all cases the engineer should be consulted as well as the architect, if serious mistakes are to be avoided. Staerkle, in 1904, found that seamstresses suffered from the newer kinds of lighting, and this was attributed to an excess of ultra-violet radiation. Schanz and Stockhausen have further investigated the effects of this kind of radiation and recommend the use of Euphor glass as a protection to the eyes, as it excludes the rays between 300 and 400 $\mu\mu$. Many experiments were carried out by them and others on animals; they proved that injury might be done to the substance of the eye and that inflammation of the outer surfaces might be caused by ultra-violet rays, which did not, however, pass through to the retina. But they used lights of such intensity as are never used in commercial work. In particular Voige showed that only the arc lamp and the quartz lamp without glass globes produce more ultra-violet light than the light of the sun; no injuries are traceable to the latter except at high altitudes; moreover, neither the quartz lamp nor the arc lamp would be used for needlework without protecting glass globes. There is the question of the increased blue and green radiation in the newer lamps. The author has carried out experiments on this point with Des Condres and others. He has found that the capacity for clear vision is less over these parts of the spectrum, if the total illumination is the same. If the coloration of the light is of no importance, this difficulty is outweighed by increased efficiency. Experiments on the fatigue of the eye have as yet given no very certain result; but subjectively it is known that green and blue lights provide agreeable sensations. For determining clearness of vision, reading tests are the simplest and best; but differences in individuals must be taken into account.

*Abstract of a Paper read before the Deutsche Beleuchtungstechinsche Gesellschaft. See "Elektrotechnische Zeitschrift," No. 9, 1919.

Nitrogen and Other Compounds in Rain and Snow

By Jacob E. Trieschmann

THE importance of anlyzing the rain and snow for nitrogen and other compounds is widley recognized, both for its agricultural and hygienic significance. Messrs. F. T. Shutt and R. L. Dorrance, of Ottawa, Canada, carried on a systematic investigation of the rain and snow covering a period of ten years, 1908—1917, the results of which have added much to our knowledge of the importance of the nitrogen compounds as an agricultural factor.

Our purpose has been to determine the amounts of the different nitrogen compounds, the chlorine, sulphates, and phosphates, in the rain and snow of this locality—a continuation of the work which has been carried on here for a number of years, the results of which have appeared in the *Chemical News* from time to time.

The work was carried out in the Cornell College laboratories under ordinary laboratory conditions. It covers a period of eight and a half months, October 1, 1918, to June 15, 1919. The samples were collected in granite pans on an open spot near the center of the town, which has a population of about 2,500.

Altogether 46 samples were investigated, of which 36 were rain and 10 were snow. This represents 22.25 inches of rain, considering 12 inches of snow equivalent to 1 inch of rain. The precipitation has supplied during the period 511.74 pounds of chlorine equivalent to 842.15 pounds of sodium chloride; also 1.509 pounds of sulphate as SO_3, and 5.2790 pounds of nitrates per acre. The phosphates as P_2O_5 amounts to only 0.0086 pound per acre.

Only 15 samples produced sufficient sulphates for determination, the highest of which, on February 28, contained 0.262 part per million; and only 11 other samples showed a slight trace. The average for the period is 0.03 part per million. An unusually mild winter, with the atmosphere comparatively free from smoke and soot, possibly explains this low average.

Five samples showed a trace of phosphate, while only four supplied a sufficient quantity for determination, the highest of which, on March 4, was only 0.03 part per million. The average is 0.002 part per million.

The chlorine content averages 11.12 parts per million, varying from 6.10 to 25.70 parts per million. Its presence in the atmosphere has been ascribed by Dr. N. Knight to salt particles carried by the winds from the Atlantic Ocean. No increase was experienced due to wind preceding or accompanying a precipitation.

The average of total nitrogen supplied for each precipitation is 1.046 parts per million. The totals for the 46 precipitations are fairly constant. Strong wind and severe electrical discharges on March 6, and on June 1 and 3, did not increase the amounts of nitrogen, but the total nitrogen supplied on these dates is unusually high, especially on May 6 and 7, the highest of the period.

The average part per million for free ammonia is 0.407; for albuminoid ammonia, 0.366; for nitrates, 0.255; and for nitrites, 0.018.

Of the total nitrogen supplied during the period, 38.85 per cent is in the form of free ammonia, 34.99 per cent albuminoid ammonia, 24.42 per cent nitrates, and 1.74 per cent nitrites.

The amount of the precipitation determines largely the total number of pounds of nitrogen supplied per acre. Yet an examination of the pounds of nitrogen supplied per acre by each of the 46 precipitations reveals a remarkable uniformity. When reduced to pounds per acre for one inch of rain, 43 of the 46 precipitations come within the narrow limits of 0.15 to 0.40 pound per acre. The wide variation in the amounts of rain, 0.05 to 2 inches, indicates a marked degree of concentration in the smaller showers. The same standard reveals that during continued precipitations, as occurred June 1 to June 6, the total nitrogen supplied gradually diminished, in this case from 0.40 to 0.20 pound per inch of rain.

There is a gradual increase in the amount of precipitation from October to 0.50 of an inch, to June with 4.6 inches for the first half of the month.

Beginning with February, there is a gradual increase of total nitrogen in parts per million 0.690 to 1.134. This with the increased amount of rain in inches, furnishes an increasing supply of nitrogen per acre to the soil during the main growing season. The increase in pounds per acre during this period is from 0.3057 pound in November to 1.3078 in June.

The 45 inches of snow supplied 13 per cent of the total 5.2790 pounds of nitrogen per acre, or 0.6911 pound. The rains supplied 87 per cent or 4.5879 pounds per acre. The rain is shown to be richer in total nitrogen content than the snow.—From *Chemical News.*

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